QUEBECOR PRINTING ATGLEN INC.

DRAFT CORRECTIVE MEASURES STUDY

17 AUGUST 1994

GES

GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.

RCRA CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

17 August 1994

DRAFT REPORT FOR USEPA REVIEW

Prepared for:
Quebecor Printing Atglen Inc.
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Atglen, PA 19310-0465

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U.S. EPA Region III
841 Chestnut Building
Philadelphia, PA 19107

CERTIFICATION

RCRA CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.

I certify that the information contained in or accompanying this RCRA Corrective Measures Study is true, accurate, and complete.

As to those identified portions of this RCRA Corrective Measures Study for which I cannot personally verify their accuracy, I certify under penalty of law that this RCRA Corrective Measures Study and all attachments were prepared in accordance with procedures designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the persons directly responsible for gathering the information, or the immediate supervisor of such persons, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fines and imprisonment for knowing violations.

Date: 8/15/94 By: Thomas E Preble

Thomas Preble
Vice President and General Manager
Quebecor Printing Atglen Inc.

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QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA
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RCRA CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

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1.0 INTRODUCTION

This Corrective Measures Study (CMS) was prepared in accordance with a Resource Conservation and Recovery Act (RCRA) Administrative Consent Order (ACO), Docket Number RCRA-3-0031H, between the United States Environmental Protection Agency, Region III (EPA) and Quebecor Printing Atglen Inc. (Quebecor). This study presents the results of the evaluation of potential corrective measures at the two areas of concern, as determined by the RCRA Facility Investigation (RFI). The CMS was prepared according to the Scope of Work described in Attachment C of the ACO.

This study takes into account all information gathered during the RFI. The RFI identified two areas of concern, the source of the releases that resulted in the areas of concern, and the composition of the releases (i.e., chemicals of concern). From that information, this report proposes the best reasonable means to protect human health and the environment, relative to chemicals of concern detected at this facility.

As determined by the RFI, this CMS considers two areas of concern at the facility. The two areas of concern include (1) a portion of the site east of the main facility building, which includes a battery of underground storage tanks (USTs) and referenced in this report as "the tankfield area", and (2) an area around the northwestern corner of the main facility building, referenced in this report as "the railroad siding area". Accidental releases of toluene/xylene-based reclaimed press solvent, as discussed in Sections 1.4.1 and 1.4.2, resulted in these areas of concern, therefore chemicals of concern for the CMS are considered to be solvent compounds.

A significant factor considered in this report is that a risk assessment completed for this site, and approved by the USEPA, showed that given the concentration, type and mobility of chemicals of concern at this site, no human health risk was present, under current conditions. Also, the risk assessment showed that there were no exposure pathways associated with site groundwater and there were ~~no~~ CoCs detected in either surface water, surface water sediments or surface soils.

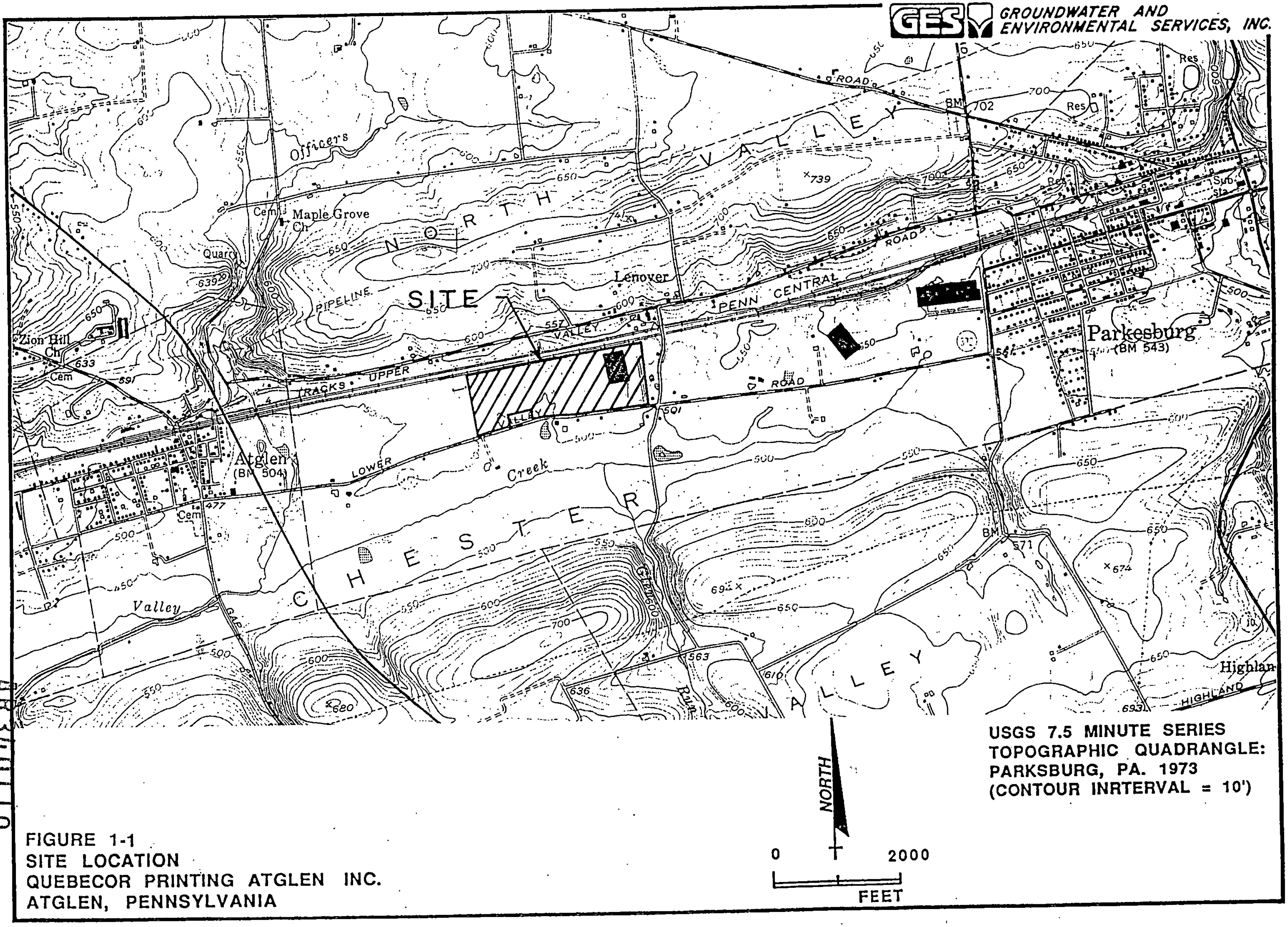
The choice of the appropriate remedial alternative also considers that the groundwater modeling program completed for this site and accepted by the USEPA has shown that chemicals of concern dissolved in groundwater will not move off site, given a 23 year scenario with no degradation of the compounds. If a conservative degradation rate of 365 days is factored into this model, the contamination will degrade faster then it can be transported and according to the model will not move off site.

A second significant factor considered in this report is that a risk assessment completed for this site, and approved by the USEPA, showed that given the concentration, type and mobility of chemicals at this site, no human health risk was present. Also, the risk assessment showed that there were no exposure pathways associated with impacted site groundwater and there were no CoCs detected in either surface water, surface water sediments or surface soils.

Section 1 of the CMS presents relevant background information about the Quebecor facility, its operations, and environmental history leading up to the CMS, as well as pertinent data summarized from the RFI. Section 2 presents an overview of the methods used for a preliminary assessment of remedial technologies. Section 3 discusses the methods and results of an in-depth evaluation of all remedial alternatives considered for this site, and Section 4 presents the recommended alternative and a conceptual design and remediation timeline.

1.1 Site Background

Quebecor is an active printing plant that has operated since 1970 in Atglen, Chester County, Pennsylvania (Figure 1-1). The facility, which prints color



USGS 7.5 MINUTE SERIES
TOPOGRAPHIC QUADRANGLE:
PARKSBURG, PA. 1973
(CONTOUR INRTERVAL = 10')

FIGURE 1-1
SITE LOCATION
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

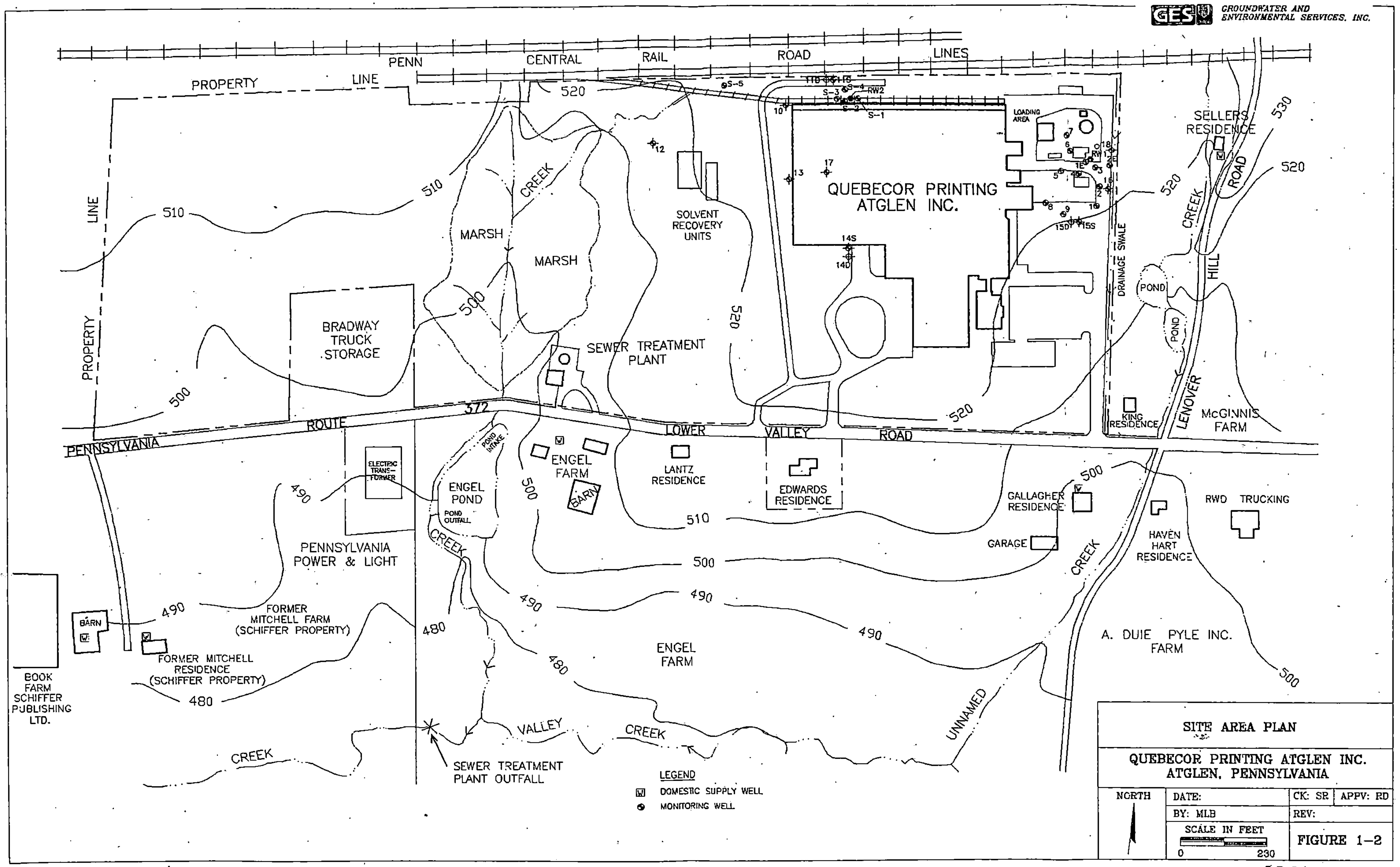
AR340110

newspaper supplements using the rotogravure method, was initially owned and operated until June 1987 by Parade Magazine (under the name Diversified Printing Corporation), from June 1987 to February 1990 by Maxwell Communication Corporation, and by Quebecor from February 1990 to the present.

The Quebecor facility is located along Lower Valley Road (Pennsylvania State Route 372), between Atglen Borough (1.0 mile west) and Parkesburg Borough (0.8 miles east), in West Sadsbury Township, Chester County, Pennsylvania. Facility access includes the main entrance, which has a paved driveway and extends the length of the eastern property boundary; a shipping entrance, which has a paved driveway to the southwest of the facility building leading to the shipping area; and a gravel road running north-south along the western building edge, which provides access to the railroad siding at the northern property boundary (Figure 1-2).

The plant is situated on the northern side of the Chester Valley and is underlain by limestone bedrock of the Cambrian-aged Conestoga Formation. The Conestoga Formation is overlain by a variable thickness of colluvial sediments (micaceous silts and clay with minor amounts of sand and gravel) which were found to be at least 30 feet deep at Quebecor as determined from monitoring and recovery well drilling records. Site surface soils consists of colluvial clays and silts of the Hagerstown-Conestoga-Guthrie association. Soil identification is based on "Soil Survey of Chester and Delaware Counties, Pennsylvania," Soil Conservation Service, United States Department of Agriculture, 1963.

The valley is drained by the westward-flowing Valley Creek, a tributary of Octorara Creek, which empties into the Susquehanna River approximately 23 miles southwest of the site. Surface drainage swales flow southward to Valley Creek on both the eastern and western edges of the developed portion of the property. Several ponds are located near the site.


GES GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.
PENN CENTRAL RAIL ROAD LINES
PROPERTY LINE
PROPERTY LINE
QUEBECOR PRINTING ATGLEN INC.
LOADING AREA
SOLVENT RECOVERY UNITS
MARSH
MARSH
CREEK
BRADWAY TRUCK STORAGE
SEWER TREATMENT PLANT
DRAINAGE SWALE
POND
POND
SELLERS RESIDENCE
CREEK
HILL
ROAD
LENOVER
KING RESIDENCE
McGINNIS FARM
PENNSYLVANIA ROUTE 372
LOWER VALLEY ROAD
ELECTRIC TRANS-FORMER
POND INTAKE
ENGEL POND
POND OUTFALL
ENGEL FARM
BARN
LANTZ RESIDENCE
EDWARDS RESIDENCE
GALLAGHER RESIDENCE
GARAGE
HAVEN HART RESIDENCE
RWD TRUCKING
PENNSYLVANIA POWER & LIGHT
FORMER MITCHELL FARM (SCHIFFER PROPERTY)
FORMER MITCHELL RESIDENCE (SCHIFFER PROPERTY)
BARN
BOOK FARM SCHIFFER PUBLISHING LTD.
ENGEL FARM
A. DUIE PYLE INC. FARM
UNNAMED CREEK
VALLEY CREEK
CREEK
SEWER TREATMENT PLANT OUTFALL
LEGEND
DOMESTIC SUPPLY WELL
MONITORING WELL
SITE AREA PLAN
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA
NORTH
DATE:
BY: MLB
CK: SR
APPV: RD
REV:
SCALE IN FEET
0
230
FIGURE 1-2

AR340112

The 57-acre Quebecor site consists of a main manufacturing/office building with associated structures, including a railroad spur line for bulk paper deliveries and a sewage treatment plant. Approximately 42 acres of the site are undeveloped. The surrounding area is a mixture of residential, agricultural, and light industrial properties. Some local area residents obtain domestic water supplies from public suppliers and others from private groundwater wells, including residences downgradient (south across Lower Valley Road) of the site. Most private groundwater wells draw on the bedrock aquifer.

1.2 Facility Operations

The facility is an active printing plant that produces newspaper inserts and Sunday supplements for various newspapers throughout the country using the rotogravure printing method. Although the facility has been upgraded since its construction in 1970, the production processes have not changed. The facility layout is depicted in Figure 1-3. The location of the sewer treatment plant is shown in Figure 1-4.

Ink is delivered to the facility in concentrated form; solvents are added to the ink to achieve proper consistency for printing. After ink is applied in the printing process, vapor and solvent recovery equipment reclaim the solvent which volatilizes as the ink dries. Solvents are stored onsite in a series of eight interconnected USTs located adjacent to the eastern property boundary. The solvent UST field consists of seven 10,000-gallon tanks and one 5,000-gallon tank. Four of these tanks were installed in 1970 (comprising the northern tank field) and the remainder were installed in 1975. All eight USTs are equipped with cathodic protection.

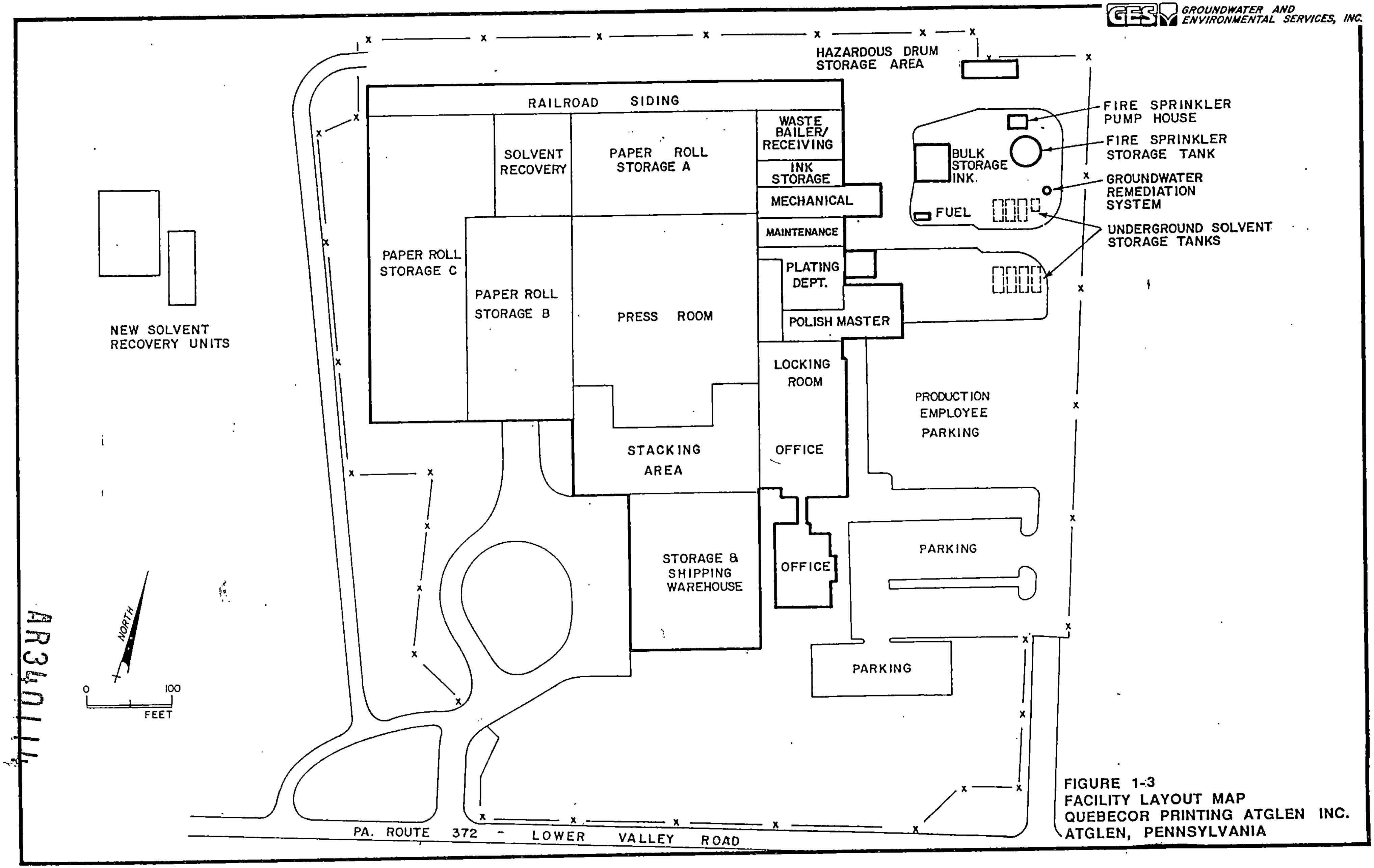
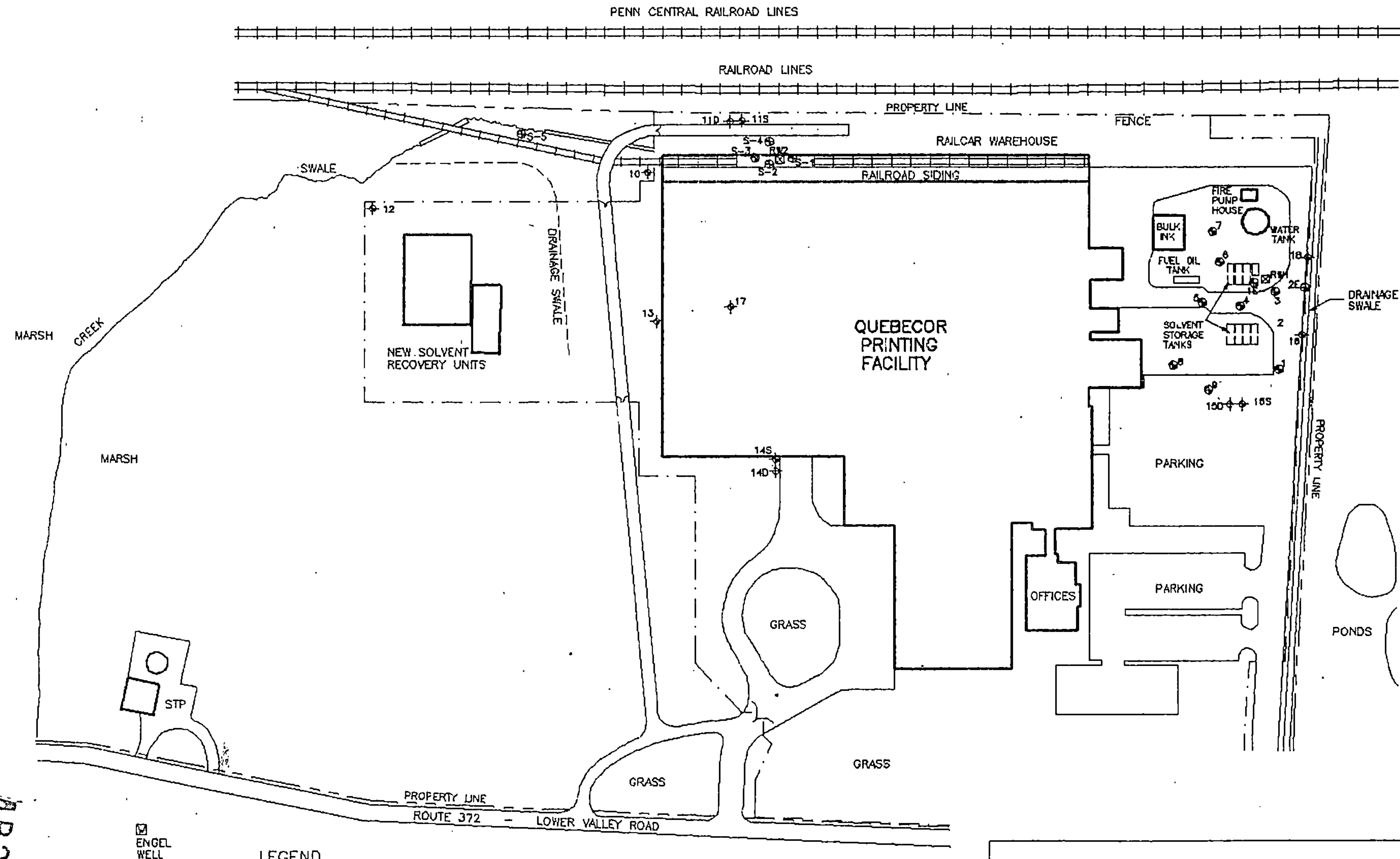


FIGURE 1-3
FACILITY LAYOUT MAP
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

AR340114

GES GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.



LEGEND

- MONITORING WELL
- RECOVERY WELL
- DOMESTIC SUPPLY WELL
- ABOVE GROUND STORAGE TANK
- UNDERGROUND STORAGE TANK
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL

AR340115

GENERALIZED SITE PLAN			
QUEBECOR PRINTING ATGLEN INC. ATGLEN, PENNSYLVANIA			
NORTH	DATE:	CK: SR	APPV: RD
	BY: MLB	REV: TITLE	
	SCALE IN FEET 0 200	FIGURE 1-4	

Solvents used by Quebecor in the printing process include "Lacolene", which consists of aliphatic hydrocarbons, and "Xylene", composed of xylene and ethylbenzene. Solvent that is recovered by facility operations is commercially referred to as "reclaimed press solvent" or "Lactol". "Xylene" is presently stored in the 5,000-gallon UST located in the northern tank field and "Lacolene" is stored in one of the 10,000-gallon USTs in the southern tank field. Reclaimed "Lactol" is stored in the other six USTs.

All of these tanks have been registered with the Pennsylvania Department of Environmental Resources (PADER) and the Pennsylvania Fire Marshal.

1.3 Permit and Regulatory Background

On 13 August 1980, Diversified Printing Corporation (DPC) filed a Notification of Hazardous Waste Activity as a treatment and/or storage facility for hazardous waste. At that time, the following wastes were identified as being treated or stored onsite:

F002 (spent halogenated solvents)
F003 (non-halogenated solvents)
F005 (non-halogenated solvents)
F006 (wastewater treatment sludges)
F007 (spent cyanide plating bath solutions)
F008 (plating bath residues)
F009 (spent stripping and cleaning bath solutions)

These materials are listed according to their RCRA waste identification code. Generated wastes included press inks, solvents, plating sludge, and machinery oils. Although originally listed as a handled waste, cyanide has never been utilized in the manufacturing process at the Quebecor facility. The facility was assigned EPA identification number PAD051397768.

On 11 November 1980, DPC submitted a Part A Hazardous Waste Permit Application to the EPA for interim status as a treatment, storage and/or disposal (TSD) facility. In this permit application, DPC listed RCRA wastes D001 (ignitable) and D002 (corrosive) as being present on site, in addition to the previously-listed RCRA wastes. However, the facility never operated as a TSD facility, which led DPC to withdraw its Part A application in February 1983. This was confirmed by PADER in a July 1983 determination. In August 1983, DPC requested that the site status be changed from TSD to generator, since hazardous waste had never been stored onsite for more than 90 days. A 1989 Quarterly Hazardous Waste Report identified hazardous wastes handled at the site as F003, F005, F006 and D001.

The sewage treatment plant on site has a National Pollutant Discharge Elimination System (NPDES) permit (number PA0045845) to discharge treated water to Valley Creek.

A groundwater remediation system in operation at the site (discussed below) is permitted by NPDES permit number PA0054933, which requires monthly sampling of the influent and effluent waters to the air stripping tower for benzene, toluene, ethylbenzene, and xylenes (BTEX), as well as reporting of the combined pumping rate for recovery wells RW-1 and RW-2 and a field measurement of effluent pH.

1.4 Previous Environmental History and Investigations Leading to the CMS

Accidental releases of "Lactol", the toluene/xylene-based reclaimed press solvent, in the past resulted in detection of these compounds in an onsite groundwater monitoring well located near the USTs. Following these releases, the USTs and product transfer lines were tested and a groundwater remediation system was installed onsite. In 1988, an accidental discharge from the solvent recovery unit resulted in the release of 3,500 to 6,000 gallons of solvent into an area north of the building. Free product recovery and other remedial actions were immediately initiated. Details of these incidents are described below.

In 1989, EPA arranged for an independent contractor, NUS Corporation (NUS), to conduct an Environmental Priorities Initiative preliminary assessment[1] of the site. Based on existing site data and the preliminary assessment results, the EPA alleged that the site might pose an "imminent and substantial endangerment to health and the environment" as defined by Section 7003(a) of the Resource Conservation and Recovery Act (RCRA), 42 U.S.C. § 6973. On 5 June 1991, Quebecor voluntarily entered into a Section 7003 Administrative Order by Consent (Consent Order).

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[1] *"Environmental Priorities Initiative Preliminary Assessment of Diversified Printing Corporation" Prepared Under TDD No. F3-8904-11, EPA No. PA-2538, Contract No. 68-01-7346, for the Hazardous Site Control Division U. S. Environmental Protection Agency, 23 October 1989, by NUS Corporation Superfund Division.*

A RCRA facility investigation (RFI) was conducted at the site in accordance with the EPA-approved RFI Work Plan. The EPA approved the RFI Report (dated 7 February 1994) on 25 March 1994 and requested this CMS.

1.4.1 UST Solvent Release

On 27 September 1985, separate-phase solvent was detected in monitoring well MW-1E, one of two groundwater monitoring wells that had been installed near the facility's UST field (Figure 1-4). A groundwater sample collected from MW-1E contained separate-phase solvent that was consistent in composition to "Lactol". MW-1E was pumped for 48 hours and the fluid was containerized in drums. Laboratory analysis of a water sample collected from MW-2E, located 75 feet east of the tank field, revealed a dissolved solvent concentration below the analytical detection limit of 2 parts per billion (ppb), as reported on the Incident Report prepared by DPC and submitted to PADER on 9 October 1985.

Subsequent investigations by Environmental Resources Management, Inc. (ERM) included pressure-testing the underground solvent storage tank system and conducting a subsurface contamination assessment of the site. The eight solvent tanks were pressure tested by the Leak Lokater LD2000 precision test method (October 1985); all eight tanks passed within the acceptable limits of the testing procedure. The associated underground piping passed with marginal test results. ERM also installed seven monitoring wells (MW-1 to MW-7) near the solvent tank field during the preliminary hydrogeologic investigation. These wells were constructed of two-inch diameter polyvinyl chloride (PVC) well casing and screen; the screens were placed to intercept the water table. Well completion depths ranged from 23 to 25 feet below grade. Drill logs of these wells with construction details are included in the RFI Workplan.

A groundwater recovery and treatment system was installed in 1986 by Groundwater and Environmental Services, Inc. (GES) following the initial investigation by ERM, which indicated that both dissolved and separate-phase hydrocarbons existed in groundwater beneath the site. The system recovered groundwater and separate-phase printing solvent by pumping from a recovery well (RW-1) and treating the recovered fluids by an air stripping tower. Treated water from this system, which has operated continuously since 1986, is discharged to a drainage swale under NPDES permit number PA0054933. Two additional monitoring wells (MW-8 and MW-9) were also installed to a depth of 30 feet to provide additional plume definition. Approximately 3,700 gallons of separate-phase solvent were recovered in the first three months of remedial system operation. Approximately 5,300 gallons of separate-phase solvent have been recovered through July 1994 from the remedial system operation. In addition, dissolved-phase solvent with an average concentration of 98 parts per million has been recovered by RW-1 since system installation, with an average withdrawal rate of 1,440 gallons per minute.

1.4.2 Surface Solvent Releases

Between 1985 and 1988, three solvent spills occurred at the site in separate instances. In December 1985, approximately 200 gallons of solvent were accidentally released in the solvent tank field. This spill was suspected to be the result of a faulty valve connection. In October 1986, a sensor failure resulted in the loss of approximately 75 to 100 gallons of "Lactol" to the groundwater treatment system effluent. In December 1986, a ruptured line resulted in the release of approximately 700 gallons of solvent in the vicinity of the solvent pump house. At the time each spill was discovered, appropriate measures were taken for solvent containment and collection, environmental impact assessment, and corrective measures to prevent future releases. Such measures are detailed in specific incident reports contained in the Administrative Record. Figure 1-5 shows the location of each of these spill incidents.

On 26 November 1988, there was an accidental surface discharge of solvent from the vapor recovery unit located in the northwest corner of the building. Due to a mechanical malfunction, solvent overflowed from a recovery tank, spilled onto the floor, and discharged through a floor drain to the railroad spur just north of the building. The spilled solvent rapidly migrated through

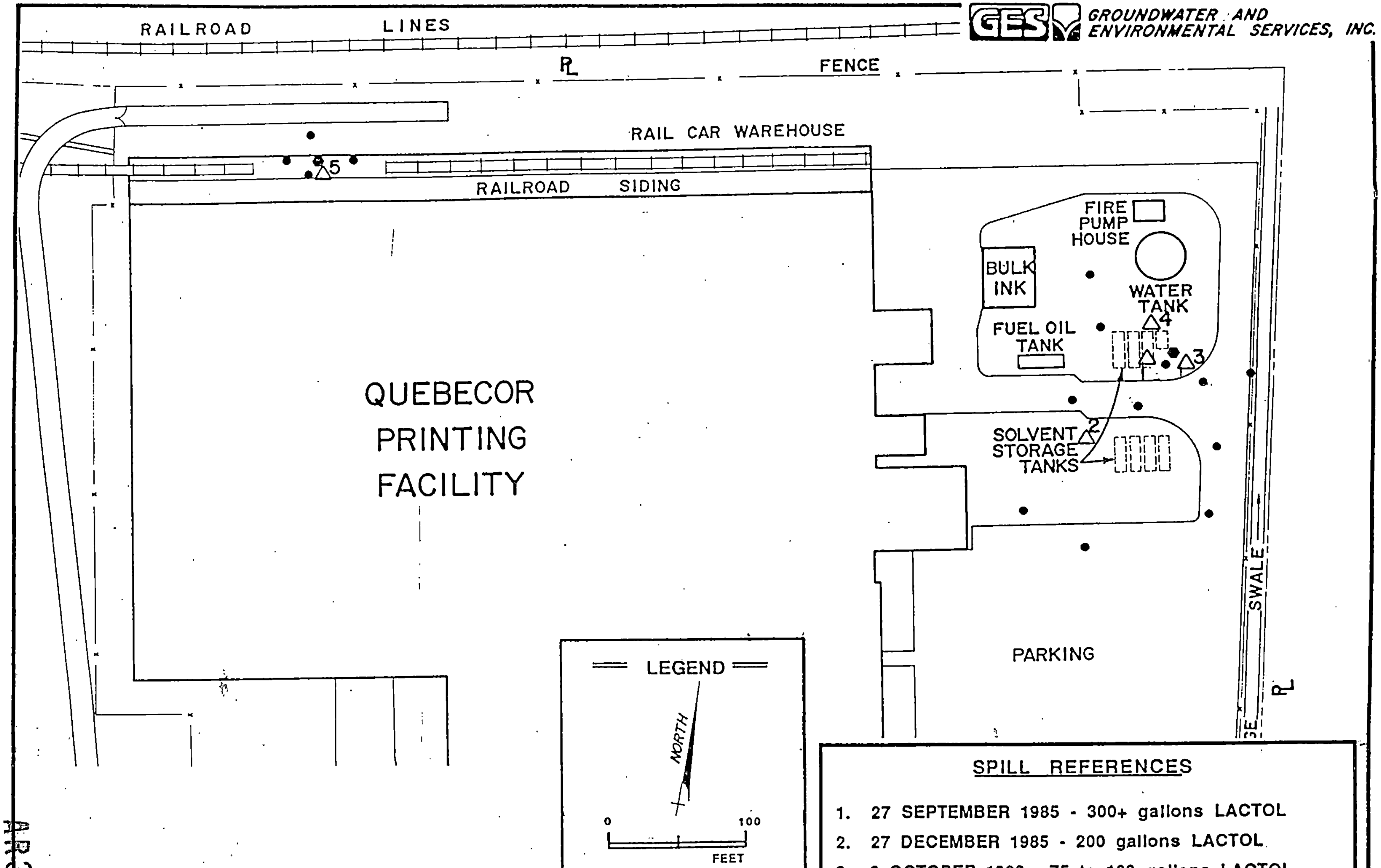


FIGURE 1-5
SPILL LOCATION MAP
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

the building's perimeter storm drain network and, aided by heavy precipitation, into a marshy area west of the building. The spilled solvent was then carried by a small stream into a pond adjacent to the south side of Lower Valley Road. Emergency response measures were immediately implemented to recover as much solvent as possible. An estimated 3,500 to 6,000 gallons of solvent were accidentally released.

Initial corrective measures were subsequently instituted by Quebecor in response to this surface spill, including extensive emergency response activities (liquid vacuum extraction from the storm drains and marsh, soil trenching and investigation, pond aeration, pond monitoring and sampling, and domestic well sampling) and subsequent restoration of indigenous pond and stream biota through controlled, gradual introduction. These activities are summarized in a 24 March 1989 letter in the Administrative Record. In addition, measures were implemented at the plant to prevent reoccurrence of similar events, as detailed in the incident report submitted to PADER (included in the Administrative Record).

Five monitoring wells (Wells S-1 through S-5) and recovery well RW-2 were installed in early 1989 in the area of the surface spill; construction details of these wells are included in the RFI Workplan. Well completion depths for S-1 through S-5 ranged from 16 to 21 feet below grade. RW-2 is connected to the existing groundwater treatment system by underground piping and a holding tank.

1.4.3 RCRA Facility Investigation Summary

The RCRA facility investigation (RFI) was initiated upon approval of the RFI Workplan on 22 July 1992. The RFI entailed the collection of physical and chemical data to determine the nature and extent of releases of hazardous material or constituents from regulated units, solid waste management units, and other potential source areas at the facility. The chemicals of concern addressed by the RFI included benzene, toluene, ethylbenzene, xylenes, tetrachloroethylene, bis(2-ethylhexyl)phthalate, cyanide, lead, phenols, and acid extractable organics. These chemicals were chosen based on the analytical database from previous sampling events. Cyanide and lead were found to be present at background concentrations across the site, including upgradient sampling locations. Findings from the RFI are summarized below.

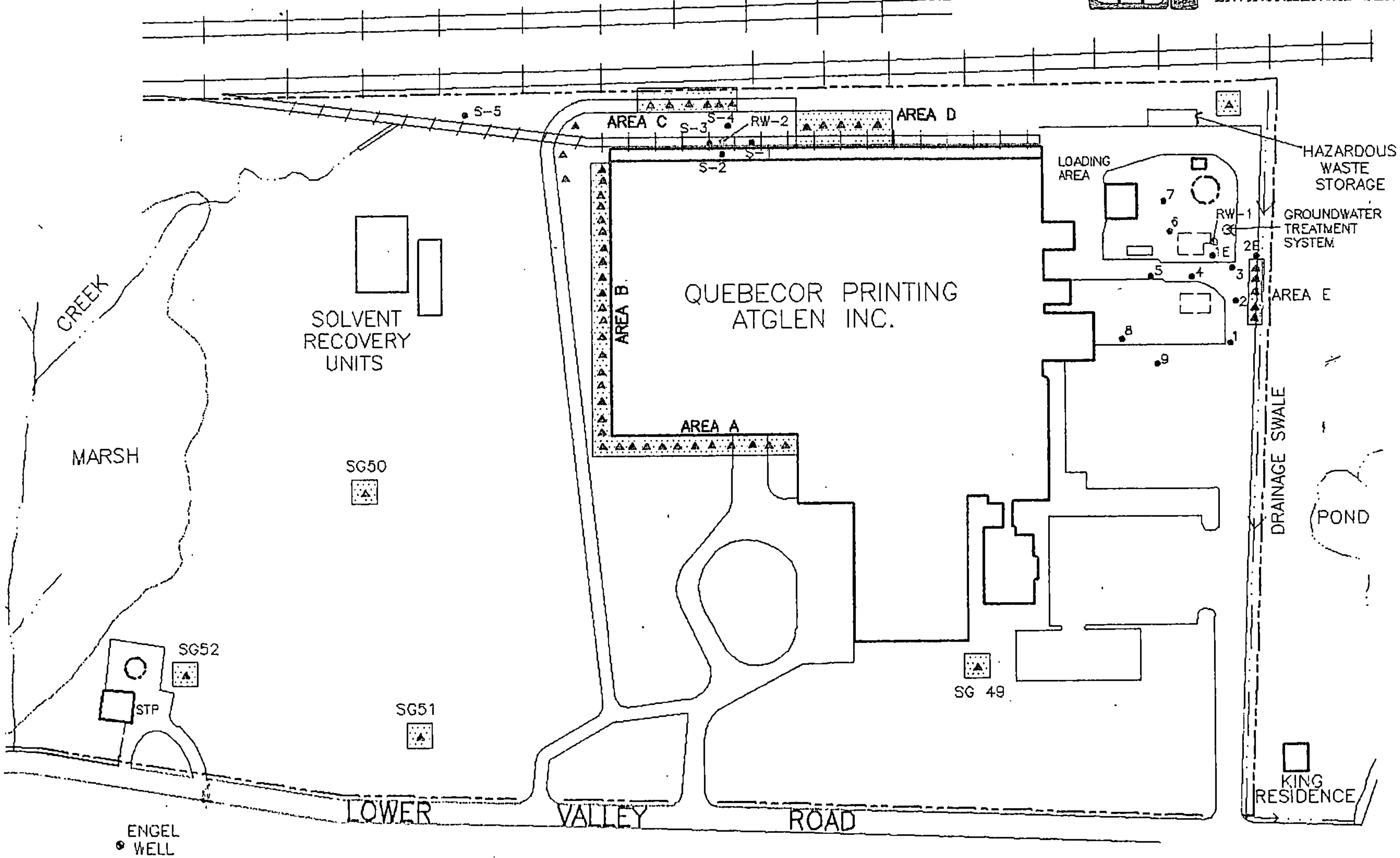
The existing remediation system recovers groundwater and separate-phase solvent through two recovery wells, RW-1 (installed in 1986 in the tankfield area) and RW-2 (installed in 1988 in the railroad siding area). Recovered groundwater is treated by a countercurrent air stripping tower (constructed in 1986) with secondary water treatment by granular activated carbon (GAC) filtration (added in 1993). Approximately 5,300 gallons of solvent have been recovered to date by this remediation system, although solvent recovery rates have declined significantly during system operation, indicating decreasing volumes of solvent in the subsurface. Water-quality monitoring in observation wells surrounding the two spill areas has shown no evidence of water-quality degradation, indicating effective control of dissolved-phase constituents by the existing recovery wells, and/or in-situ degradation and attenuation rates that equal or exceed the rate of dissolved-phase transport.

A soil gas survey revealed no areas of concern other than the tankfield area and railroad siding area. This survey comprised 55 sampling points (Figure 1-6) along the southwest and northern perimeters of the building, along the eastern perimeter of the site property, and at other randomly-selected points.

Surface water and stream sediment samples were collected from eight locations on and surrounding the site (Figure 1-7). No volatile organic compounds (VOCs) or solvent indicator compounds were detected in any of these samples. Bis(2-ethyl hexyl)phthalate was detected in five surface water sediment samples with concentrations ranging from 0.4 to 1.4 mg/kg.

Eight shallow monitoring wells (MW-10 to MW-18) and three deep monitoring wells (MW-11D, MW-14D, and MW-15D) were installed at the site as part of the required RCRA monitoring well network (see Figure 1-4). The shallow wells

GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.



LEGEND

- • MONITORING WELL
- RECOVERY WELL
- DOMESTIC WELL
- UNDERGROUND STORAGE TANK
- ABOVE GROUND STORAGE TANK
- ▲ SOIL GAS POINTS
- AREAS OF SOIL GAS INVESTIGATION

AREAS OF SOIL GAS INVESTIGATION

QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

NORTH	DATE:	CK: SR	APPV: RD
	BY: MLB	REV:	
	SCALE IN FEET 0 160	FIGURE 1-6	

were drilled to completion depths of 17 to 30 feet and were screened to intercept the water table. Two deep wells (MW-11D and MW-14D) were completed as open holes with total depths of 49 and 102 feet; the third deep well (MW-15D) was installed with screen and riser casing due to overburden collapse during drilling. MW-15D was screened in the bedrock. Bedrock cores collected during the drilling of the deep wells confirmed that the bedrock at the site is the Conestoga Formation. Significant water-bearing fractures were observed in MW-11D, but not in MW-14D. No bedrock cores were obtained from MW-15D due to overburden collapse. VOC concentrations above method detection limits (MDLs) were present only in soil samples collected by split-spoon sampling from MW-10.

Two rounds of groundwater samples were collected from all non-solvent bearing wells installed before the RFI and once from all wells installed during the RFI. During the first sampling event, conducted in September 1992 on the pre-RFI wells, concentrations of VOCs were detected in MW-3, MW-6, and S-4 ranging from 0.230 milligrams per liter (mg/l) in MW-6 to 2.73 mg/l in S-4. Concentrations of semi-volatile (acid- and base/neutral-extractable) compounds (BNAs) were detected in monitoring wells MW-3, MW-5, S-1, and S-4 The second sampling event, conducted in March 1993, included all wells at the site. Monitoring wells MW-4, RW-1, and S-3 contained separate-phase solvent and were not sampled. VOC concentrations were detected in MW-3, MW-6, MW-10, RW-2, S-1, and S-4; total VOC concentrations ranged from 0.230 mg/l in MW-6 to 55.35 mg/l in S-1. BNAs were detected in wells MW-3, MW-12, RW-2, S-1, and S-4. BNA compounds benzoic acid, cresols (cresylic acid), and bis(2-ethylhexyl)phthalate had maximum detectable concentrations of 0.100 mg/l, 0.980 mg/l, and 0.011 mg/l, respectively. No other targeted BNAs were detected.

Rising-head slug tests were performed on six shallow monitoring wells. The aquifer parameters estimated from these slug tests indicate a range of hydraulic conductivities from 1.15×10^{-6} centimeters per second (cm/sec) to 2.63×10^{-5} cm/sec. Hydraulic conductivity values derived for the overburden at this site appear to be representative of the overburden lithologies observed during the installation of monitoring wells. Based on tables referenced in

Groundwater And Wells (Driscoll, 1986) typical hydraulic conductivity values for sandy silts and clayey sands, which are represented at this site, range from 10^{-6} to 10^{-4} cm/sec. These values indicate very low groundwater rates of movement in the unconsolidated sediments and soils affected by solvent constituent were restricted to these lithologies.

Short-term (48-hour) pumping tests were performed on the three deep monitoring wells; MW-14D and MW-15D sustained groundwater yields of less than 1 gallon per minute (gpm), while MW-11D had a sustained yield of less than 6 gpm. Results from the pumping test on MW-11D suggest a transmissivity for the aquifer of approximately 367.8 ft^2/day (0.2554 ft^2/min).

A method-of-characteristics (MOC) groundwater model was used to evaluate potential movement of dissolved benzene, ethylbenzene, xylenes, toluene, and bis(2-ethylhexyl)phthalate in groundwater at the site. The model was constructed based on worst-case conditions (i.e., maximum contaminant concentrations and hydraulic gradients, and no degradation of contaminants). After a modeled period of 23 years, the existing solvent plume showed no evidence of movement offsite and was not near the site boundaries or any potable water-supply well. When natural contaminant degradation was included in the model, even less plume movement was noted over the 23-year model period.

1.4.3.1 Risk Assessment Summary

A baseline human health-based risk assessment was performed at the Quebecor facility for each area of concern as part of the RFI. This risk assessment was accepted by the EPA on 25 March 1994 with the RFI Report.

Potential human exposure routes were considered for each of six transfer media (groundwater, surface soil, subsurface soil, surface water, surface water sediment and air). Three exposure routes were identified and exposure scenarios for chemicals of concern were developed for each route. These scenarios considered (1) contact with contaminated surface water sediments by children or adolescents playing in adjacent streams, (2) contact with contaminated soils by workers onsite, and (3) inhalation of vapors from air stripper emissions by facility employees. No exposure routes were identified for potential contact with groundwater, surface water, or surface soils. Risk calculations for naturally-occurring compounds are not discussed in this section. Risk calculations for the three exposure scenarios described indicate risk levels below risk-based guidelines that USEPA has used at other sites.

1.4.3.1.1 Characterization of Groundwater

The results of the RFI have shown that all impact associated with this site is confined onsite to soils and groundwater located in the unconsolidated overburden zone, extending from approximately 15 to 40 feet below grade. A computer modeling program was completed to predict movement of groundwater and transport of CoCs within the overburden. The results of this model were included with the RFI, and approved by USEPA. The model predicted that chemicals of concern dissolved in groundwater will not move off site, given a 23 year scenario, and considering no natural degradation of the compounds.

There are no potable or irrigation wells on the Quebecor site, and the groundwater model indicates that impacted groundwater will not move offsite. Therefore, there are no reasonable exposure scenarios which would lead to contact with impacted groundwater, and no risk scenarios have been assessed for this media.

1.4.3.1.2 Characterization of Surface Soils

During the RFI, six soil samples were collected from the 0 foot to 2 foot range. Each of these samples was analyzed for the parameters specified in the RFI Workplan. No chemicals of concern relative to the Quebecor facility were detected in any of the samples. For this reason, no risk assessment was completed for exposure to impacted surface soils.

1.4.3.1.3 Characterization of Surface Water

During the RFI, eight surface water samples were collected from various locations across the site. Each of these samples was analyzed for the parameters specified in the RFI Workplan. No chemicals of concern relative to the Quebecor facility were detected in any of the samples. For this reason, no risk assessment was completed for exposure to impacted surface water, relative to chemicals of concern found on this site.

1.4.3.1.4 Risk Characterization of Surface Water Sediments

The subpopulation with the highest potential for exposure to surface water sediments includes children and adolescents playing in or around the drainage swales or surface water bodies near the site. Chemicals of concern for this exposure scenario are bis(2-ethylhexyl)phthalate (DEHP), and naturally-occurring lead and cyanide. Risk values were calculated for DEHP and cyanide using three different exposure scenarios: sediments located at the east end of the property (the tankfield area), sediments located at the west end of the property (railroad siding area), and random exposure across the entire site. No risk was calculated for lead since a reference dose (RfD) does not exist.

For DEHP, risk values were calculated assuming both carcinogenic and noncarcinogenic potential. Assuming that the chemical is carcinogenic, the highest risk value, obtained by multiplying the chronic daily intake (CDI) value by the slope factor (SF), was determined to be 1.6×10^{-8}. The EPA generally regards any risk value less than 1×10^{-6} as not constituting a potential hazard.

For noncarcinogenic chemicals, any hazard quotient less than one (1) is not considered to constitute a risk. The following table lists the highest hazard quotient calculated for each of the three scenarios described above for naturally-occurring cyanide and DEHP:

Exposure Scenario	DEHP	Cyanide
Entire Site	$1.3x10^{-8}$	$5.4x10^{-8}$
Tankfield Area	$1.4x10^{-8}$	$7.2x10^{-9}$
Railroad Siding	$5.0x10^{-9}$	$1.0x10^{-7}$

This assessment concluded that contact with surface water sediments at any location at the facility does not constitute a risk.

1.4.3.1.5 Risk Characterization of Subsurface Soils

The subpopulation with the highest potential for exposure to subsurface soils includes construction and utility workers at the facility. Exposure durations by this pathway were considered to be two years and therefore subchronic (i.e., between two weeks and seven years). Chemicals of concern for this exposure scenario are ethylbenzene, toluene, xylenes, lead, and cyanide. Risk values were calculated for ethylbenzene, toluene, xylenes using three different scenarios: sediments located at the east end of the property (the tankfield area), sediments located at the west end of the property (railroad siding area), and random exposure across the entire site. No risk was calculated for lead since a RfD for lead does not exist. The remaining chemicals of concern are all noncarcinogenic compounds.

The hazard quotients for contact with ethylbenzene, toluene, and xylenes in subsurface soils were calculated following the methodology described above. As noted, all of these chemicals are noncarcinogenic and the hazard quotient for this exposure pathway is less than one. Therefore, considering the worst-case scenario presented in this report, no risk is present.

The following table lists the highest hazard quotient calculated for each of the three scenarios described above for ethylbenzene, toluene, xylenes, and naturally-occurring cyanide:

Exposure Scenario	Ethylbenzene	Toluene	Xylene	Cyanide
Entire Site	$8.9x10^{-10}$	$1.7x10^{-7}$	$6.0x10^{-8}$	$2.2x10^{-10}$
Tankfield Area	$7.0x10^{-10}$	$8.3x10^{-11}$	$4.0x10^{-9}$	$4.6x10^{-11}$
Railroad Siding	$1.1x10^{-9}$	$2.0x10^{-7}$	$8.8x10^{-8}$	$2.8x10^{-10}$

The assessment concludes that contact with surface soils at the facility does not constitute a risk.

1.4.3.1.6 Risk Characterization of Air Stripper Vapor Emissions

The subpopulation with the highest potential for exposure to vapor emissions from the air stripper comprises employees at the facility. For the purposes of calculating risk, an exposure duration of 30 years (i.e., chronic) was conservatively assumed. The chemicals of concern for this exposure scenario were benzene and toluene.

For benzene, risk values were calculated assuming a carcinogenic potential. The highest risk value, obtained by multiplying the CDI value by the SF, was determined to be $5x10^{-6}$.

For toluene (noncarcinogenic), the hazard quotient obtained by dividing the chronic exposure intake by the RfD value was determined to be 0.015. For noncarcinogenic chemicals, any hazard quotient less than one is not considered to constitute a risk.

1.4.3.2 RCRA Facility Investigation Report

A final RCRA Facility Investigation Report was completed for this site and submitted to EPA on 7 February 1994. The RFI demonstrated that two areas of concern at the facility have been affected: the tankfield area, located on the east end of the main facility building, and the railroad siding area, located near the northwestern corner of the building. Data collected from the soil gas survey, soil borings, surface water and sediment sampling, and water samples collected from both shallow and deep monitoring wells have defined both the lateral and vertical extent of impact in the unconsolidated overburden and groundwater. The RFI was approved by the EPA on 25 March 1994.

2.0 PRELIMINARY ASSESSMENT OF TECHNOLOGIES

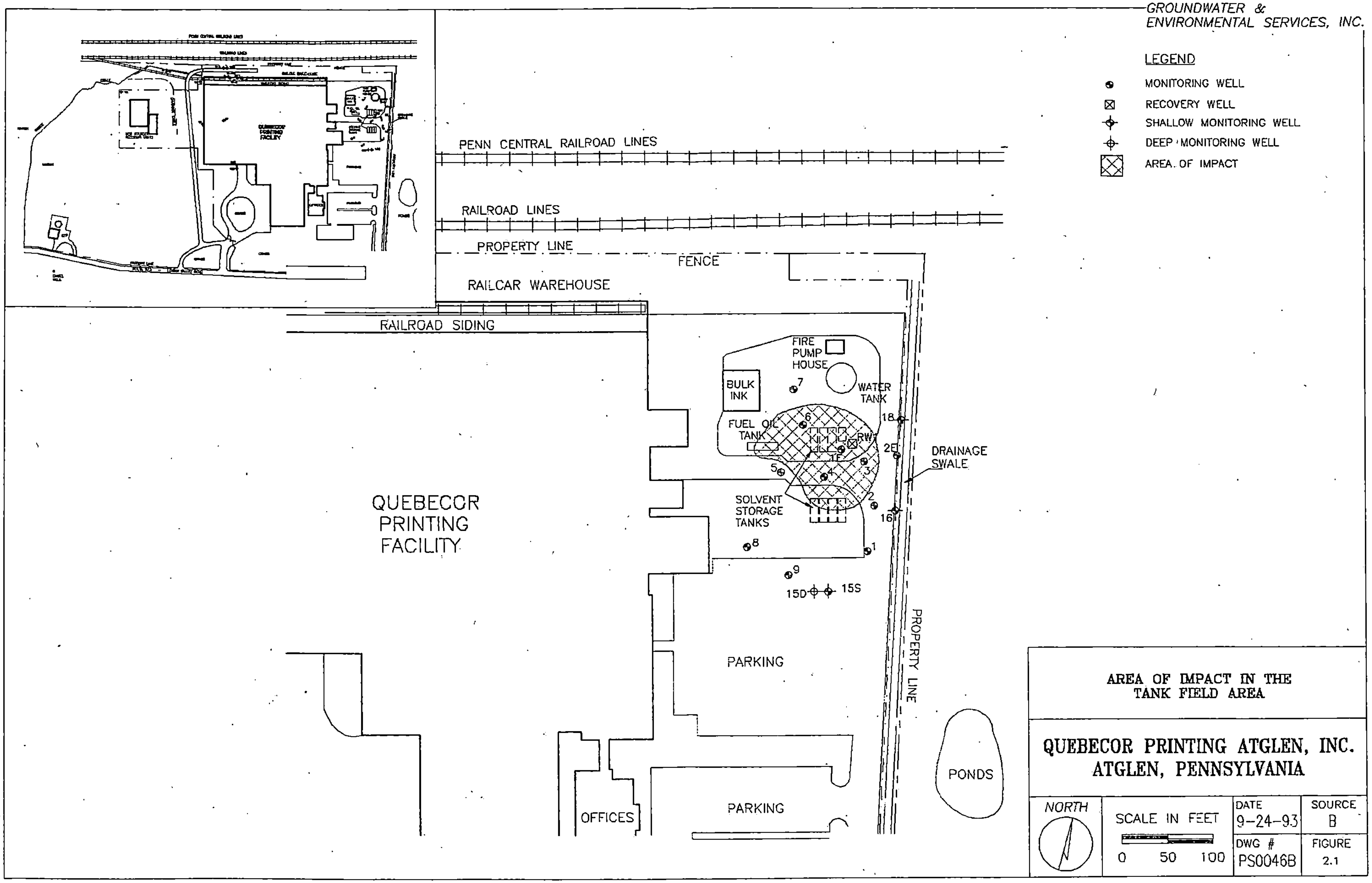
2.1 CMS Objectives and Methods

The objective of this CMS is to evaluate and determine corrective measure alternatives that eliminate human health risks or risks to the environment surrounding the facility, relative to chemicals of concern (CoCs) detected at this site.

The methods needed to meet this objective will consider that a complete risk assessment for this site (submitted by Quebecor as part of the RFI report and approved by the EPA) has shown that given the type, location, concentration, and mobility of CoCs found at the Quebecor facility, no reasonable exposure scenarios currently exist which will lead to unacceptable human health risks. Results of the RFI report have also shown that no chemicals of concern directly linked to this site were detected in surface water, surface soils or surface water sediments. Also, groundwater modeling completed for this site, as part of the RFI, and approved by USEPA, shows that impacted groundwater will not migrate off site.

Since no unacceptable health risks were detected during the completion of the risk assessment, considering current site conditions, the corrective measure chosen for this site will be designed to protect human health and the environment under current as well as future conditions by limiting the potential for degradation of the environment. The protection will take into account potable aquifers located beneath this site.

Figures 2-1 and 2-2 identify the boundaries of the two affected areas on the site, as defined by information gathered during the RFI and during pilot tests conducted as part of this CMS. The extent of this impact is generally the same as was considered during the risk assessment process and the groundwater modeling tasks.


GROUNDWATER &
ENVIRONMENTAL SERVICES, INC.
LEGEND
MONITORING WELL
RECOVERY WELL
SHALLOW MONITORING WELL
DEEP MONITORING WELL
AREA OF IMPACT
PENN CENTRAL RAILROAD LINES
RAILROAD LINES
PROPERTY LINE
FENCE
RAILCAR WAREHOUSE
RAILROAD SIDING
FIRE PUMP HOUSE
BULK INK
WATER TANK
FUEL OIL TANK
RW1
DRAINAGE SWALE
SOLVENT STORAGE TANKS
QUEBECOR PRINTING FACILITY
15D
15S
PROPERTY LINE
PARKING
PONDS
OFFICES
PARKING
AREA OF IMPACT IN THE TANK FIELD AREA
QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA
NORTH
SCALE IN FEET
0 50 100
DATE 9-24-93
SOURCE B
DWG # PS0046B
FIGURE 2.1

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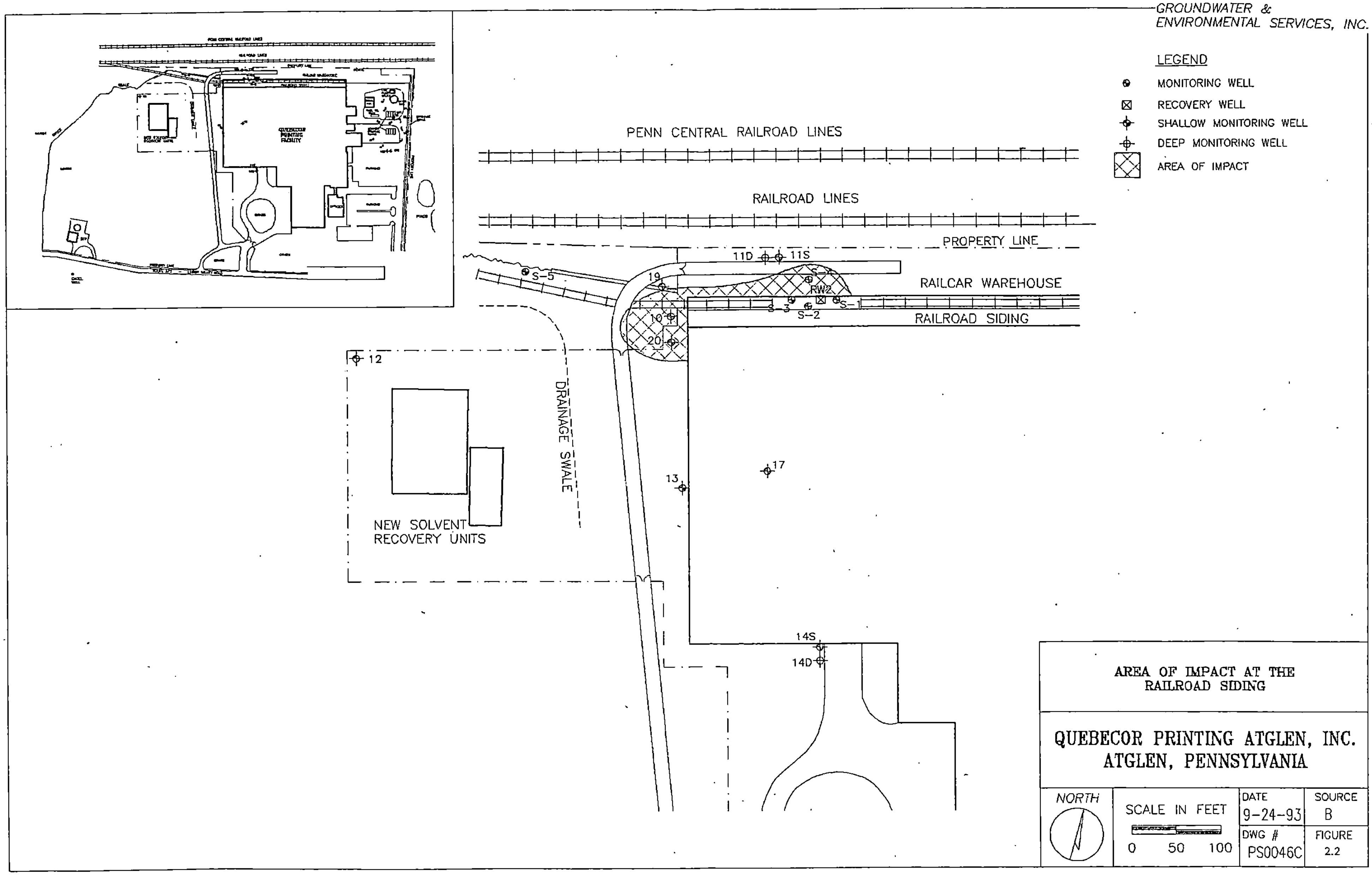

GROUNDWATER & ENVIRONMENTAL SERVICES, INC.
LEGEND
MONITORING WELL
RECOVERY WELL
SHALLOW MONITORING WELL
DEEP MONITORING WELL
AREA OF IMPACT
PENN CENTRAL RAILROAD LINES
RAILROAD LINES
PROPERTY LINE
RAILCAR WAREHOUSE
RAILROAD SIDING
11D
11S
S-5
19
RW2
S-3
S-2
S-1
10
20
12
DRAINAGE SWALE
NEW SOLVENT RECOVERY UNITS
13
17
14S
14D
AREA OF IMPACT AT THE RAILROAD SIDING
QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA
NORTH
SCALE IN FEET
0 50 100
DATE 9-24-93
SOURCE B
DWG # PS0046C
FIGURE 2.2

AR340135

Considering these affected areas, and the information known about the subsurface conditions at this site, some of the initial remedial alternatives outlined in Task II of the RFI Workplan, may be applicable to this site. This CMS will define which of these alternatives is most effective at achieving the objectives of this study. Should more than one option be determined effective, the most efficient option will be chosen.

2.2 Preliminary Corrective Actions

As part of the evaluation, it is important to consider that Quebecor has already instituted extensive changes in the handling, storage, and operation of the solvent system to prohibit the possibility of future solvent release to the environment. In the tankfield area substantial system changes have been instituted in 1993 and 1994. These initial steps include the following:

- An onsite 5,000-gallon fuel oil UST, formerly located immediately west of the existing solvent storage tank battery was removed in April 1994. The removal of this tank eliminates a potential future source of groundwater impact; no UST will be installed in its place.
- All eight underground solvent storage tanks are scheduled to be removed in September 1994. On 12 July 1994, the Pennsylvania Department of Environmental Protection (PADER) was informed that the tanks would be removed. The removal of all underground storage tanks and lines greatly decreases the potential for leaking USTs to impact soils and groundwater currently or in the future. No solvent USTs will be installed in place of these tanks.
- Quebecor has constructed all new aboveground tanks, and transfer lines to replace the USTs. These above ground tanks nearly eliminate the potential for leakage to enter the subsurface. Further, updated tank-filling equipment eliminates the potential for tank overfills, which could impact the subsurface.

- Quebecor has instituted a rigorous maintenance, inspection, and testing program of all solvent-handling controls. This program is designed to identify and eliminate problems which could lead to releases.
- A state-of-the-art loading and unloading dock has been installed in the vicinity of the bulk ink storage building. This dock is designed to prevent any release of chemicals to the environment which could occur during the loading and unloading of chemicals.

A complete summary of the engineering designs incorporated into each of the above referenced preliminary corrective actions is included in Appendix E.

In the railroad siding area, engineering practices and system modifications were instituted in 1988 - 1989, in response to the solvent surface release of November 1988. These preventive maintenance measures, which were instituted to prevent reoccurrence of a similar event, were documented in the incident report submitted to the PADER (included in the USEPA Administrative Record). These measures have been effective and no releases have occurred in this area in the past six years.

These remedial steps already undertaken, or planned, will improve groundwater quality by eliminating a potential source of impact (the solvent USTs and impacted soil immediately surrounding these tanks). These measures will also provide current and future protection of human health and help protect groundwater quality from future degradation.

All of these factors, designed to eliminate potential, existing sources of impact, and prevent future releases, will be considered in the final suggested corrective action for this site.

2.3 Evaluation of Corrective Measure Technologies - Initial Screening

The remainder of this section is generally derived from Section 3 of the RFI Workplan (Pre-Investigative Evaluation of Remedial Alternatives). In summary, Section 3 of the RFI Workplan included a Pre-Investigative Evaluation of Remedial Alternatives which were thought to be potentially feasible at this site. All of those alternatives are presented in Table 2-1.

Options were primarily considered relative to protection of human health and the environment. Secondary consideration was given to the overall applicability of the option to the site. Each of the preliminary options were reviewed and evaluated against the following basic criteria:

<u>Site Characteristics</u>

- can the option physically be implemented on the site ?

<u>Waste Characteristics</u>

- does the option eliminate the contamination or simply transfer it from one media to another; and, if the option does generate waste, does the amount of waste potentially outweigh the benefits of remediating the existing condition ?

<u>Technological Limitations</u>

- is the technology effective to this site ?
- is the technology reliable ?
- is the technology proven overall ?

The RFI indicated limited impact to the subsurface, as well as a lack of mobility of subsurface contamination. Therefore, several of the remedial alternatives which provide immediate stabilization of contaminants, but at relatively high cost, were eliminated at this point in the review (i.e., stabilization, *ex-situ* treatments, and several unconventional remedial alternatives such as steam stripping and soil mixing). Criteria including cost-effectiveness, familiarity with the process, and availability of vendors were factored into this decision.

2.4 Evaluation of Corrective Measure Technologies - Second Phase Screening

Potential remedial alternatives identified during development of the RFI Workplan were initially compared against several selection criteria and ranked as to their suitability (as discussed in Section 2.3); alternatives that were considered to meet or exceed these criteria were passed on to a more intensive second phase screening (discussed in Section 3). Remedial options that did not pass this initial evaluation were dropped from further consideration.

All remedial technologies which were passed on for further evaluation for the Quebecor site were assessed in light of the results of the RFI risk assessment, which determined that no risk exists under the current site conditions, and the results of groundwater modeling conducted during the RFI, which determined that no offsite migration of chemicals of concern is expected. Throughout the review process, each option was also considered against the no action scenario, to determine if the benefits of remediation outweigh no further action.

TABLE 2-1

INITIAL SCREENING OF CORRECTIVE MEASURE TECHNOLOGIES

QUEBECOR PRINTING ATGLEN INC.

ALTERNATIVE	DESCRIPTION	COMMENTS	PASS/ FAIL
SINGLE ALTERNATIVES			
NO ACTION	No corrective measures to be taken.	This option is included to provide a basis for comparison with other corrective measures.	**
NO ACTION (With Monitoring)	Monitoring only of site wells and potable wells.	Since no risk has been detected and impacted ground-water is immobile, monitoring is used to confirm the no risk scenario.	Pass
PUMP AND TREAT	Removal and treatment of impacted groundwater and treatment of some soil.	Proven, non-destructive technology known to be effective at the Quebecor site. Passes all initial screening criteria.	Pass
SOIL VAPOR EXTRACTION	Removal of hydrocarbon impact from soil by forced air withdrawal through the unsaturated zone.	Proven, nondestructive technology known to remediate impacted soil in a relatively short time frame. Passes all initial screening criteria.	Pass
IN SITU BIOREMEDIATION	Destruction of hydrocarbons from both the saturated and unsaturated zone through enhancement of naturally-occurring microorganisms.	Proven, nondestructive technology, capable of treating saturated and unsaturated zones. Minimal waste generated through this option. Passes all initial screening criteria.	Pass
IN SITU STEAM STRIPPING	Removal of contamination in the unsaturated zone by forcing steam into the soils.	Experimental technology, not proven. Much less effective in clay-rich soils; maintenance intensive. Fails technological screening criteria.	Fail
IN SITU DETOXIFIER	Removal of contaminants from soils by a mechanical unit which strips volatiles from soils with subsurface mixing blades and hot air.	Experimental technology; reliability and effectiveness not proven. Very destructive, very high capital cost. Fails technological criteria.	Fail

** - No action alternative fails to achieve the objective but passes the screening because it is used as a baseline for comparison with other corrective measure alternatives.

TABLE 2-1 (CONTINUED)

INITIAL SCREENING OF CORRECTIVE MEASURE TECHNOLOGIES

QUEBECOR PRINTING ATGLEN INC.

ALTERNATIVE	DESCRIPTION	COMMENTS	PASS/ FAIL
IN SITU VITRIFICATION	Use of intense heat to convert soil to a glassy substance. Contaminates are locked into the vitrified matrix.	Experimental technology; overall reliability and implementability are uncertain. Potentially very destructive. Very high costs associated with mobilization, testing, and power supply. Maintenance intensive. Fails technological criteria.	Fail
IN SITU SOIL MIXING	Stabilization of impacted material by augering into soil and adding a slurry to both the saturated and unsaturated zones.	Degree of stabilization of volatiles is unproven (more effective on metals). Subsurface utilities limit this option. May not be effective in semi-competent bedrock. Fails technological criteria.	Fail
AIR SPARGING	Increased volatilization of hydrocarbons by injecting air into the subsurface (saturated zone).	Non-destructive technology, relatively low cost, can remediate both soil and water. Passes all initial screening criteria.	Pass
BIOLOGICAL SOIL VENTING	Biological enhancement of either soil vapor extraction or air sparging.	Nondestructive technology known to remediate impacted soils and groundwater in a relatively short time frame. Passes all initial screening criteria.	Pass
SLURRY WALL	Containment of impact by constructing an impermeable boundary in front of the contaminant plume, from surface to bedrock.	Does not treat contaminants, may be very difficult to create an impermeable boundary at this site. Fails site and technological screening criteria.	Fail
ON SITE INCINERATION	Excavation of impacted material followed by incineration of soil in a mobile kiln.	Destructive; difficult to permit; political concerns; costly. No appropriate staging area available.	Fail
ABOVEGROUND BIOREMEDIATION	Excavation of soil, spreading the soil in an 18-inch thick layer and tilling and aerating the soil to promote natural degradation of hydrocarbons.	Limited available area on site to spread soil; process is ineffective in cold weather; highly destructive and disruptive. Fails site characteristics.	Fail

TABLE 2-1 (CONTINUED)

INITIAL SCREENING OF CORRECTIVE MEASURE TECHNOLOGIES

QUEBECOR PRINTING ATGLEN INC.

ALTERNATIVE	DESCRIPTION	COMMENTS	PASS/ FAIL
ABOVEGROUND SOIL WASHING	Excavation of impacted soil, followed by washing the soil with a mixture of water, surfactant, and solvent.	Technology may introduce another contaminant (i.e., solvent). Leachate from the process is difficult to collect and would also need to be treated. Fails technical criteria.	Fail
SOIL REMOVAL	Excavation of affected soil; transport and disposal of material off site, at either a landfill or incinerator.	Appropriate disposal of soil would requires a a disposal facility which will accept large quantities of impacted material. Also difficult to excavate some material on the site due to physical obstructions. Passes initial screening criteria; however, has limited applicability.	Pass

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2.4.1 Second Phase Screening Review Process

Each options included in Section 3 has been evaluated based on the criteria stated in Attachment 'C' of the AOC; through site-specific conditions known to exist; and by specific information gathered during the RFI. These factors are elaborated below:

Site-Specific Conditions

Site-specific conditions were considered in the process of remedial option evaluation and cost estimation. RFI sampling results were used to determine the applicability of individual options. Although a number of conditions were evaluated, the site-specific factors which were ultimately given the most serious consideration are summarized below:

- rate of groundwater movement, as summarized by pump and slug testing, and groundwater modeling
- potential exposure pathways know or anticipated to be present and human health risks associated CoCs detected on the site
- local geology (soil profile, rock type, weathering characteristics)
- local hydrogeology (depth to water, hydraulic conductivity, preferred zones of hydrologic communication)
- type of contamination present (persistence, volatility, solubility)
- degree of site impact (estimated area and volume, average concentration of contaminants)

Some pertinent specific information from the RFI relative to these factors is discussed below.

1. Groundwater modeling programs completed for this site and accepted by the USEPA have shown that chemicals of concern dissolved in groundwater will not move off site, given a 23 year scenario with no degradation of the compounds. If a conservative degradation rate of 365 days is factored into this model, the contamination will degrade faster then it can be transported, and according to the model will not move offsite.

2. A risk assessment completed for this site, and approved by the USEPA, showed that of the potential exposure pathways associated with CoCs at this site, no risks were determined to exist.

3. CoCs associated with this site were not detected in the site's surface soil, surface water, or surface soil sediments.

4. Local geologic materials are characterized by low to very low permeability, resulting in a limited capacity for subsurface transmission of fluids or air.

5. All impact on the site is limited to two specific areas: the tankfield area (east of the main building) and the railroad siding area (northwest of the building). The boundaries of impact defined in each of these areas is shown on Figures 2-1 and 2-2.

6. Groundwater yields from monitoring wells installed in the unconsolidated overburden will be no more than 3 gallons per minute.

7. Separate-phase product is locally encountered on the water table.

8. The areas to be addressed for corrective measures encompasses the currently-defined area of site impact.

9. Vertical contaminant migration is not an issue, since site impact is due to solvent products with a density of less than 1.0. This suggests that vertical recharge of the bedrock aquifer through the unconsolidated water-table zone is limited in the areas currently known to contain light non-aqueous phase liquids (LNAPLs). Consideration of the location of groundwater springs along topographic highs associated with bedrock outcrops north of the Chester Valley was also given in this factor.

10. Site access for remedial equipment and heavy machinery is limited due to the location of the facility manufacturing building and other physical obstructions.

11. The current USTs near RW-1 are being removed from service; the removal of these tanks, and associated, impacted soils surrounding the tanks will be considered the remediation of a potential source.

2.4.2 Results of Second Phase Screening Review

As noted, each remedial alternative that passed these initial screening criteria is evaluated in detail in Section 3. Table 2.1 provides detailed comments on whether the options passed or failed the screening criteria. In summary, the following remedial alternatives passed this preliminary review:

- No Action (with site monitoring)
- Pump and Treat
- Soil Vapor Extraction
- In-situ Bioremediation
- Air Sparging
- Biologic Enhancement by Soil Venting
- Soil Removal with Offsite Disposal

3.0 EVALUATION OF CORRECTIVE MEASURE ALTERNATIVES

3.1 Introduction

This section of the CMS provides an in-depth analysis of each corrective measure technology that passed the initial screening criteria (discussed in Section 2). These corrective measure technologies, or options, (listed in Table 3-1 and Table 3-2) were chosen for their ability to reduce or eliminate human health risk, their potential implementability on the site, technological reliability, and (limited) waste-producing characteristics. Each selected option was then evaluated by comparing how well it matched several selection criteria. These criteria, and considerations associated with each, are listed below.

	Criterion	Considerations
1.	Useful Life	Ability of the system to perform without significant changes or reconditioning.
2.	Frequency and Complexity of Maintenance	Overview of required maintenance needed to maintain short- and long-term effectiveness.
3.	Advantages	Ability to preserve or enhance the current no-risk circumstances, and its ability to reduce toxicity, mobility, or volume of chemicals of concern.
4.	Disadvantages	Inability to preserve or enhance the current no-risk circumstances, and its inability to reduce toxicity, mobility, or volume of chemicals of concern.
5.	Risk Protection	How, specifically, will the option to preserve or enhance the current no-risk circumstances.
6.	Limiting Factors	Significant limits to the option's overall effectiveness.

7. Relative Effectiveness — Degree to which the option can protect human health. Secondarily, degree to which option can successfully remediate hydrocarbon contamination. The extent to which each option could address more than one medium was not factored into the effectiveness rating.

8. Relative Cost — The costs required to implement each technology in relation to the range of costs estimated for all corrective measure alternatives.

9. Relative Time Line — Anticipated time required for the option to achieve beneficial results. The following guidelines were utilized in assigning time line rankings:

--short:	2 years or less
--medium:	between 2 and 7 years
--long:	more than 7 years

[Note: for single options, this ranking can be somewhat misleading, since most listed technologies address only soil contamination and not the combined impact to soil and groundwater. Tables 3-1 and 3-2 shows that options that address soil remediation are almost universally effective within a short time. In contrast, options that primarily address groundwater (such as pump-and-treat) typically require an extended time to be fully effective.

All of the combined options were accompanied by medium time lines, primarily driven by the time needed for groundwater remediation in relatively low-permeability subsurface materials.]

10. Waste Generation — Volume and type of wastes generated by each option.

11. Implementability to Tankfield or Railroad Siding Areas — Implementability of the option, considering both above- and below ground physical, geological, and hydrogeological limitations.

TABLE 3-1
SUMMARY OF REMEDIAL ALTERNATIVES
TANKFIELD AREA
QUEBECOR PRINTING ATGLEN INC.

ALTERNATIVE	TREATED MEDIUM	RELATIVE EFFECTIVENESS	RELATIVE TIME LINE	RELATIVE COST	RELATIVE FEASIBILITY	TECHNICAL EVALUATION CRITERIA PASS/FAIL	SITE SPECIFIC APPLICABILITY PASS/FAIL	COMBINED CRITERIA PASS/FAIL
IN SITU TREATMENT								
NO ACTION	None	Low	Long	Low	Low	Fail	Pass	Fail
SITE MONITORING	None	Low	Long	Low	Low	Pass	Pass	Pass
PUMP & TREAT	Groundwater; some soil	Moderate	Long	Moderate	High	Fail	Pass*	Fail
VAPOR EXTRACTION	Soil; some groundwater	Moderate	Short	Low	Moderate	Fail	Pass*	Fail
BIOREMEDIATION	Soil and groundwater	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
AIR SPARGING	Groundwater and soil	Moderate	Short	Moderate	Moderate	Fail	Fail	Fail
BIOLOGIC ENHANCEMENT BY SOIL VENTING	Groundwater and soil	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
EX SITU, ON-SITE								
INCINERATION	Soil only	High	Short	High	Low	Fail	Fail	Fail
ABOVE GROUND BIOREMEDIATION	Soil only	Moderate	Moderate	Moderate	Moderate	Fail	Fail	Fail
EX SITU, OFF-SITE								
DISPOSAL AND LANDFILLING OR INCINERATION	Soil only	High	Short	High	Low	Pass	Pass	Pass
COMBINED ALTERNATIVES								
PUMP & TREAT/ SOIL VAPOR EXTRACTION	Groundwater and soil	High	Moderate	Moderate	High	Pass	Pass	Pass
PUMP & TREAT/ SOIL DISPOSAL	Groundwater and soil	Moderate	Moderate	Moderate	High	Fail	Pass	Fail
VAPOR EXTRACTION & BIOREMEDIATION	Groundwater and soil	High	Moderate	Moderate	Moderate	Pass	Fail	Fail

* = Only fully applicable if used as an element of a combined remedial plan

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TABLE 3-2
SUMMARY OF REMEDIAL ALTERNATIVES
RAILROAD SIDING AREA
QUEBECOR PRINTING ATGLEN INC.

ALTERNATIVE	TREATED MEDIUM	RELATIVE EFFECTIVENESS	RELATIVE TIME LINE	RELATIVE COST	RELATIVE FEASIBILITY	TECHNICAL EVALUATION CRITERIA PASS/FAIL	SITE SPECIFIC APPLICABILITY PASS/FAIL	COMBINED CRITERIA PASS/FAIL
IN SITU TREATMENT								
NO ACTION	None	Low	Long	Low	Low	Fail	Pass	Fail
SITE MONITORING	None	Low	Long	Low	Low	Pass	Pass	Pass
PUMP & TREAT	Groundwater; some soil	Moderate	Long	Moderate	High	Fail	Fail	Fail
VAPOR EXTRACTION	Soil; some groundwater	Moderate	Short	Low	Moderate	Fail	Pass*	Fail
BIOREMEDIATION	Soil and groundwater	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
AIR SPARGING	Groundwater and soil	Moderate	Short	Moderate	Moderate	Fail	Fail	Fail
BIOLOGIC ENHANCEMENT BY SOIL VENTING	Groundwater and soil	Moderate	Moderate	High	Moderate	Pass	Fail	Fail
EX SITU, ON-SITE								
INCINERATION	Soil only	High	Short	High	Low	Fail	Fail	Fail
ABOVE GROUND BIOREMEDIATION	Soil only	Moderate	Moderate	Moderate	Moderate	Fail	Fail	Fail
EX SITU, OFF-SITE								
DISPOSAL AND LANDFILLING OR INCINERATION	Soil only	High	Short	High	Low	Fail	Fail	Fail
COMBINED ALTERNATIVES								
PUMP & TREAT/ SOIL VAPOR EXTRACTION	Groundwater and soil	High	Moderate	Moderate	High	Pass	Pass	Pass
PUMP & TREAT/ SOIL DISPOSAL	Groundwater and soil	Moderate	Moderate	Moderate	High	Pass	Fail	Fail
VAPOR EXTRACTION & BIOREMEDIATION	Groundwater and soil	High	Moderate	Moderate	Moderate	Pass	Fail	Fail

* = Only fully applicable if used as an element of a combined remedial plan

Along with the screening criteria listed above, all options will automatically consider the preliminary remediation efforts (tank removal, engineering practices, and updated equipment designs) already undertaken at the facility.

These remediation efforts make provisions for either the elimination of a potential source or for safeguards against future releases. The measures will provide means to prevent further degradation to the environment and reduce the potential for increasing the amount of impact at the site. Because of these provisions, site conditions will at least remain static from conditions modeled in the RFI and are anticipated to improve due to natural biodegradation.

A detailed presentation of the compliance of each corrective measure alternative with these criteria is contained in Section 3.3.

3.2 Field-Testing of Selected Corrective Measure Alternatives

Several potential corrective measure alternatives were field-tested after completion and approval of the RFI but prior to the aforementioned evaluation. This testing was performed to help determine the feasibility of using these options at the Quebecor site. The field testing also provided data for site-specific design criteria such as extraction point spacing, vacuum pump sizing, and treatment system design specifications for various vapor extraction scenarios. Hydrologic parameters derived from historical data (from operation of the existing groundwater extraction and treatment system at the site) were incorporated into this database. A discussion of field-testing methods and results is presented in Appendices A and B (soil vapor extraction) and Appendices C and D (bioremediation).

3.3 Evaluation of Individual Corrective Measure Alternatives

A discussion of individual corrective measure alternatives, including descriptions of the methods and criteria evaluations, is presented on the attached detail sheets. Corrective measure alternatives are presented in the following sequence:

- no further action
- *in situ* treatment
- *ex situ,* on-site treatment
- *ex situ,* off-site treatment
- combined options

The combined options represent a group of cost-effective and time-effective corrective measure alternatives that pass all of the major evaluation criteria. Unlike the individual options, the combined options all address contamination in both soils and groundwater at the site. These combined options are presented following the single-option summaries.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
NO ACTION
Page 1 of 2

ALTERNATIVE   No action.

METHOD DESCRIPTION

No action.

ADVANTAGES

- Non-destructive.
- No capital costs; no operation and maintenance (O&M) costs.

DISADVANTAGES

- Does not address contaminants either in soil or groundwater.
- Does not make provisions to prevent potential contaminant migration.
- Provides no means to monitor long-term site conditions.

RISK PROTECTION

- This option would not monitor existing impact and would provide no means to monitor groundwater migration.
- This option would create no pathways for exposure to chemicals of concern and would create no risk.

TYPICAL PRIMARY SYSTEM COMPONENTS

- None.

LIMITING FACTORS

- None.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
NO ACTION
Page 2 of 2

RELATIVE EFFECTIVENESS	**Low**	Moderate	High
RELATIVE COST	**Low**	Moderate	High
RELATIVE TIME LINE	Short	Moderate	**Long**

IMPLEMENTABILITY

- Nothing to implement.

WASTE GENERATION

- No waste would be generated.

ADDITIONAL COMMENTS

A groundwater model, completed as part of the RFI, shows that offsite migration of contaminants is unlikely. Further, RFI risk assessment results show that no risk is present, relative to onsite contaminants. This option provides no means to verify the groundwater model with time, therefore protection from risk cannot be confirmed.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

SITE MONITORING

Page 1 of 2

ALTERNATIVE Site Monitoring.

METHOD DESCRIPTION

Site monitoring only, including quarterly sampling of downgradient domestic supply wells near the facility, quarterly sampling of selected sentinel wells, and annual sampling of site groundwater monitoring wells. This method would monitor the stability of impacted groundwater which has been predicted to be immobile and unrelated to any applicable exposure pathways.

ADVANTAGES

- Non-destructive.
- No capital costs; low operation and maintenance (O&M) costs.
- Meets technical, environmental and human health objectives.
- Meets the objectives of the CMS.

DISADVANTAGES

- Does not address contaminants either in soil or groundwater.
- Does not make provisions to prevent potential contaminant migration.

RISK PROTECTION

- This option would protect human health and the environment from future risk by monitoring existing impact and verifying that no migration of groundwater occurs.
- This option could create exposure pathways for technicians who would sample the monitoring wells; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.

TYPICAL PRIMARY SYSTEM COMPONENTS

- Existing site groundwater monitoring wells.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SITE MONITORING
Page 2 of 2

LIMITING FACTORS

- May require a deed restriction should the site ever be considered for anything other than current usage.

RELATIVE EFFECTIVENESS	**Low**	Moderate	High
RELATIVE COST	**Low**	Moderate	High
RELATIVE TIME LINE	Short	Moderate	**Long**

IMPLEMENTABILITY

- Nothing to implement.

WASTE GENERATION

- No waste would be generated.

ADDITIONAL COMMENTS

A groundwater model, completed as part of the RFI, shows that offsite migration of contaminants is unlikely. Further, RFI risk assessment results show that no risk is present, relative to onsite contaminants. Quarterly sampling of onsite sentinel monitoring wells would provide confirmation of plume immobility and provide an early detection system should any contaminant migration occur. Therefore, since there is no risk and no potential for impacted groundwater migration, the site monitoring option would be an acceptable option for this site.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
UNDERGROUND STORAGE TANK REMOVAL
Page 1 of 3

ALTERNATIVE Removal of USTs in the tankfield area.

METHOD DESCRIPTION

Although tank removal is not specifically a "remediation option" and will not address soil or groundwater impact directly, the eight USTs currently located in the tankfield area may be a source of current and future releases of toluene-based solvents. Therefore, by removing these tanks, a potential source of continuing contamination would be eliminated.

All USTs would be removed by excavating material from around the tanks, and residual product in the tanks would be vacuumed out. Prior to removal from the excavation, each UST would be inerted and then individually cut open, cleaned of all residual wastes, and disposed of as scrap metal. All residual wastes removed from the tanks would be disposed of as hazardous materials.

USEFUL LIFE OF THIS ALTERNATIVE

Since this option involves removing a potential contaminant source, and no new USTs will be installed, the useful life is indefinite.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

There is no maintenance associated with this option.

ADVANTAGES

- Immediate results, since a potential source of release is mitigated.
- Relatively inexpensive.
- Very short time frame needed to complete the option.
- Eliminates the potential for increasing the volume of contaminant released at the site.
- No complex technologies involved.
- No associated operation and maintenance costs.
- Minimal waste generation.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
UNDERGROUND STORAGE TANK REMOVAL
Page 2 of 3

DISADVANTAGES

- Accomplishes minimal soil cleanup and does not cleanup groundwater.

RISK PROTECTION

- This option could create exposure pathways for construction workers removing the USTs; adherence to a health and safety plan, which will be completed specifically for this job, will eliminate these health risks.

TYPICAL PRIMARY SYSTEM COMPONENTS

No specific system would be installed. All equipment utilized for tank removal, including excavation equipment and trucks, are only needed for the duration of the project. The entire UST removal process is anticipated to take approximately one to two weeks.

LIMITING FACTORS

- Underground utilities and adjacent structures.
- Possibility of heath concerns unless strict health and safety guidelines are followed.

RELATIVE EFFECTIVENESS	Low	Moderate	**High**
RELATIVE COST	**Low**	Moderate	High
RELATIVE TIME LINE	**Short**	Moderate	Long

IMPLEMENTABILITY

Underground utilities are the only limiting factor. Utilities will be marked out prior to the commencement of tank removal.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

UNDERGROUND STORAGE TANK REMOVAL

Page 3 of 3

WASTE GENERATION

Wastes generated by this option will consist of heavily-impacted soils (defined as soils saturated with separate-phase product or soil which when screened with an organic vapor analyzer have a reading or greater than 1,000 units) removed from around the USTs. All removed soil will be temporarily stored onsite until it can be properly disposed.

ADDITIONAL COMMENTS

The USTs at this site will be removed sometime between 15 August 1994 and 31 December 1994. Tank removal will be completed by a State of Pennsylvania-licensed UST contractor. Within 60 days of completion of the tank removal, a closure report will be submitted to all involved agencies, including PADER and USEPA.

APPLICABILITY IN THE TANKFIELD AREA

This option will be implemented in the tankfield area.

APPLICABILITY IN THE RAILROAD SIDING AREA

There are no USTs at the railroad siding; therefore, applicability of this option is not relevant.

PASS/FAIL

This option passes and will be implemented in the tankfield area.

This option is not applicable to the railroad siding area.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
GROUNDWATER EXTRACTION AND DECONTAMINATION
Page 1 of 4

ALTERNATIVE Groundwater Extraction and Decontamination (Pump-and-Treat)

METHOD DESCRIPTION

This option involves the extraction and decontamination of groundwater affected by volatile and semi-volatile organic compounds, followed by discharge of the water to a surface stream, sanitary sewer system, and/or reinfiltration to the subsurface. Groundwater can be extracted with recovery wells and/or trenches and is then treated using a variety of treatment methods, typically air stripping and/or granular activated carbon (GAC) filtration. Separate-phase product accumulated at the pumping well is recovered to the surface.

USEFUL LIFE OF THIS ALTERNATIVE

Major components of a groundwater extraction and remediation system, including wells and/or trenches, piping, and the stripper tower, typically last for the duration of the project. Pumps and blowers used in the system can be anticipated to last from 1.5 to 5 years. However, premature deterioration of system components may occur due to physical conditions, such as silt accumulation in trenches and recovery well filter packs, which may lead to reduced water recovery and increased wear on pumping components. Adverse water quality, such as high contents of dissolved metals and salts, can cause precipitation and mineral build-up inside pipes and stripper towers, which can eventually hinder the operation of the system.

Independent studies have shown that pump-and-treat systems, even when properly designed, may not remediate groundwater to regulated levels. Since dissolved concentrations of VOCs in the pumped influent will generally reach an asymptotic equilibrium over time, when most of the groundwater impact has been remediated, continued pumping may not be advantageous (Makdisi and Gervason, 1991).

FREQUENCY AND COMPLEXITY OF MAINTENANCE

Pump-and-treat systems must be maintained at least weekly for general system and operational checks and at least monthly for thorough system checks. These check can include items such as cleaning, sampling, and tower repacking, and granular activated carbon changes. Most system maintenance can be completed by a technician. System components are easily available through many suppliers, and are generally not quickly outdated or frequently upgraded.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
GROUNDWATER EXTRACTION AND DECONTAMINATION
Page 2 of 4

ADVANTAGES

- Relatively non-destructive.
- Relatively moderate capital cost (dependent on type of treatment).
- Reduction/elimination of separate-phase product on the water table.
- Reduction of the potential for additional contaminant migration.
- Technology has been field-tested and proven effective.

DISADVANTAGES

- Long duration with long-term operation and maintenance costs.
- Does not directly address contamination within the unsaturated zone (except where treated groundwater reinfiltration is utilized).
- Increased capital costs and O&M costs for vapor-phase treatment.

RISK PROTECTION

- This option could create exposure pathways for maintenance workers servicing the system; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.
- If carbon is used as a means to treat effluent air or water from the stripper, all saturated carbon will need to be disposed of as a hazardous waste. This transfers impact from one media to another, potentially creating a health hazard and exposure pathway.

TYPICAL PRIMARY SYSTEM COMPONENTS

One or more recovery wells and/or trenches are installed to a sufficient depth below the water table to allow continuous pumping at a calculated optimum rate. Construction of a decontamination system follows, typically including air stripping and/or granular activated carbon. Affected groundwater can also be treated by a variety of methodologies including high-cost options such as aerobic biological degradation.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

GROUNDWATER EXTRACTION AND DECONTAMINATION

LIMITING FACTORS

This method is less effective in low-permeability silt- and clay-rich soils, due to limited recovery well flow and lateral influence, reduced capacity for reinfiltration of treated water, and increased adsorption of organic compounds to clay minerals. Contaminant capture is difficult in bedrock due to high degree of subsurface heterogeneity and anisotropy. Air stripping technology is less effective in the removal of dissolved-phase heavy-end organic compounds.

RELATIVE EFFECTIVENESS	Low	**Moderate**	High
RELATIVE COST	Low	**Moderate**	High
RELATIVE TIME LINE	Short	Moderate	**Long**

IMPLEMENTABILITY

This option can be implemented in either the tankfield area or at the railroad siding; however, there are applicability limitations for each area (see below).

WASTE GENERATION

The air stripper technology used in this option would likely require carbon treatment as both a final polish prior to water discharge and to treat gases emitted from an air stripper. The carbon will become saturated with volatile organics over time, and the spent carbon from these units must be disposed of as a hazardous waste. The rate at which carbon becomes spent is proportional to the concentration of VOCs in extracted groundwater and the airflow rate.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
GROUNDWATER EXTRACTION AND DECONTAMINATION

APPLICABILITY IN THE TANKFIELD AREA

The existing remedial system installed in the tankfield area is a groundwater pump-and-treat system utilizing one recovery well, capable of producing 3 to 4 gallons per minute, and a stripper tower with GAC carbon polish on the effluent. This system has operated for approximately 7 years. Due to the low permeability of the fine-grained soils in this area, however, the cone of influence created by the single pumping well is sufficient to capture affected groundwater from only a small portion of the entire tankfield area.

Therefore, an improved pump-and-treat system would need to incorporate several additional collection points (e.g., wells) in the tankfield area to expand the area of hydraulic control.

Further, studies have shown that for a typical hydrocarbon spill (specifically gasoline), less than 5 percent of the contaminant mass is dissolved in the groundwater.[1]

APPLICABILITY IN THE RAILROAD SIDING AREA

Due to extremely low soil permeability in the railroad siding area and the location of most of the groundwater impact, conventional groundwater recovery methods (i.e., wells or trenches) are not considered to be applicable. Other groundwater recovery options, however, may be more effective; water recovered by alternative methods can still be treated by air stripping or similar technologies.

PASS/FAIL

Groundwater extraction is applicable in the tankfield area, but has the potential to generate waste (spent carbon); remove otherwise immobile groundwater; and continue for an extended duration, due to slow treatment caused by limited groundwater withdrawal potential. For these reasons, this option will not be considered as a stand-alone alternative for a final determination.

Groundwater extraction is not applicable as a stand-alone remediation option in the railroad siding area since the ability to extract water from recovery wells in the railroad siding is severely limited.

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1 Wilson and Brown, 1989, Groundwater Monitoring Review, Winter 1989, pp. 173-179.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL VAPOR EXTRACTION
Page 1 of 4

ALTERNATIVE Soil Vapor Extraction (SVE)

METHOD DESCRIPTION

This option is able to removal volatile and semi-volatile organic compounds from soils in the unsaturated zone. VOCs in soil gas are extracted with vertical and/or horizontal vapor extraction wells/trenches; passive and/or forced air inlet wells may be used, primarily in the areas of maximum hydrocarbon impact, to increase the rate of air influx to the subsurface, thus enhancing volatilization.

USEFUL LIFE OF THIS ALTERNATIVE

When properly designed and installed, the life of an SVE system is generally indefinite. The only portions of the system likely to deteriorate are the blower motor or the vacuum pump motor. Generally this equipment has a life expectancy of approximately 3 years.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

The operation and maintenance requirements for a SVE system are minimal. Weekly visits are typically required to check for proper system operation and to make necessary adjustments. If a GAC unit is added to treat recovered vapors, then the carbon must be changed when it becomes saturated. The rate at which carbon becomes saturated is dependent on the concentration of recovered vapors and the extraction flow rate.

ADVANTAGES

- Relatively nonrestrictive.
- Relatively moderate capital cost.
- Relatively short duration; long term O&M costs should be limited.
- Can enhance naturally-occurring biodegradation by oxygenating subsurface.
- Can reduce/eliminate separate-phase product on water table.
- Can reduce levels of dissolved VOCs in groundwater.
- Technology has been field-tested and proven effective.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL VAPOR EXTRACTION

DISADVANTAGES

- Does not directly address soil contaminants within saturated zone.
- Future changes to air quality regulations increases likelihood of the need for vapor-phase treatment, increasing both capital and O&M costs.

RISK PROTECTION

- This option could create exposure pathways for maintenance workers installing and servicing the system; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.
- If carbon is used as a means to treat effluent air from the extraction system, all saturated carbon would need to be disposed of as a hazardous waste. This transfers impact from one media to another, potentially creating a health hazard and exposure pathway.

TYPICAL PRIMARY SYSTEM COMPONENTS

A series of vapor extraction wells is installed to depths just above the water table. A series of air induction wells (optional) may be installed just beyond the area of most significant soil impact. One or more vacuum blowers or vacuum pumps capable of moving sufficient air to create and maintain a constant vacuum are installed in a central location. A condensation vessel, or drop-out tank, is installed between the extraction wells and the vacuum pump to remove water from the influent vapor stream. Finally, a vapor-phase treatment system is added to reduce VOCs in vapor emissions prior to discharge to the atmosphere. Most commonly, carbon adsorption is used for low-flow systems and catalytic oxidation or incineration is used for high-flow systems.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL VAPOR EXTRACTION
Page 3 of 4

LIMITING FACTORS

This method is less effective in fine-grained, clay- or silt-rich soils due to reduced subsurface air flow, limited radius of vacuum influence, and contaminant removal rate. This method is also less effective in high-moisture soils due to tendency of water particles to inhibit volatilization. The type of contaminants present may also limit system effectiveness; long-chain, low-mobility hydrocarbons generally cannot be removed from soils by volatilization.

RELATIVE EFFECTIVENESS	Low	**Moderate**	High
RELATIVE COST	**Low**	Moderate	High
RELATIVE TIME LINE	**Short**	Moderate	Long

ADDITIONAL COMMENTS

In general, system effectiveness is directly related to the air formation permeability and contaminant volatility; the limitations of low-permeability soils may be offset to a certain extent by reducing extraction well spacing. This option generally is most effective in combination with active water-table depression, which allows removal of adsorbed contaminants from a larger unsaturated zone created below the normal water table. Capping of the surface with a low-permeability material can induce greater lateral airflow through the subsurface, potentially enhancing hydrocarbon volatilization.

IMPLEMENTABILITY

This option is considered to be implementable in both the railroad siding and the tankfield area.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

SOIL VAPOR EXTRACTION

Page 4 of 4

WASTE GENERATION

A soil vapor extraction system would likely require the addition of carbon treatment to the effluent air discharge. High-concentration vapors would have to be treated by either oxidation units or a thermal destruction unit; once vapor concentrations are significantly reduced, they can be treated with granular activated carbon. Since carbon has a useful life, and will become saturated with volatile organics over time, the spent carbon from these units must be disposed of as a hazardous waste. The rate at which carbon becomes spent is proportional to the concentration of volatile in extracted air and the air flow rate.

APPLICABILITY IN THE TANKFIELD AREA

A pilot test conducted on two existing wells in the tankfield area (see Appendix A) showed that high-vacuum extraction produced an induced vacuum of approximately 200 inches of water, and that a radius of influence of approximately 25 to 38 feet could be achieved. The test also showed that after two hours of extraction, volatile organic concentrations in air were detected at 530 ppm (as recorded with an organic vapor monitor) and at a lower explosive limit (LEL) of 13%. These results suggest that soil vapor extraction could be feasible in the tankfield area.

APPLICABILITY IN THE RAILROAD SIDING AREA

A pilot test conducted on two existing wells in the railroad siding area (see Appendix B) showed that high-vacuum extraction produced a vacuum of approximately 200 inches of water, and a radius of influence of approximately 17 to 31 feet could be achieved. The test also showed that after eight hours of extraction, volatile organic concentrations in air were detected at 50 ppm (as recorded with an organic vapor monitor). These results suggest that soil vapor extraction could be feasible in the railroad siding area.

PASS/FAIL

This option passes for both areas; however, has the potential to generate waste (spent carbon).

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
***IN SITU* BIOREMEDIATON**
Page 1 of 4

ALTERNATIVE *In situ* bioremediation

METHOD DESCRIPTION

This method involves the biodegradation of petroleum hydrocarbons by stimulating naturally-occurring microorganisms to decontaminate subsurface materials affected by volatile and semi-volatile organic compounds. Injection wells, trenches and/or surface infiltration may be utilized to physically and/or chemically introduce oxygen and nutrients to the subsurface environment.

USEFUL LIFE OF THIS ALTERNATIVE

When properly designed and installed, the life of a bioremediation system is generally indefinite. The only portions of the system likely to fail are groundwater pumps or mechanical components associated with the addition of nutrients and oxygen to the groundwater. Generally such equipment has a life expectancy of approximately 1.5 to 3 years.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

Key requirements for operation include insuring that (1) adequate dissolved oxygen and the proper pH are maintained in the re-injected groundwater, (2) the proper ratio of nitrogen and phosphorus is maintained in the re-injected groundwater, (3) the groundwater is recovered and re-injected at a rate sufficient to maintain hydraulic control and inhibit contaminant migration, and (4) that surface applications, if necessary, are applied at a rate that prevents ponding of the water.

Key requirements for maintenance include regular inspections so that all pumps, valves, and switches operate properly; the integrity of the piping system is maintained; the required supplemental pH, nutrient, and dissolved oxygen feeds are maintained at proper levels; and the required utilities are adequately supplied to the treatment system.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
***IN SITU* BIOREMEDIATON**
Page 2 of 4

ADVANTAGES

- Relatively non-destructive.
- Technology is effective for removal of both light- and heavy-end hydrocarbon compounds.
- Addresses contamination in both the saturated and unsaturated zones.
- Can eliminate separate-phase product on the water table and reduce dissolved hydrocarbon in the groundwater. Biosurfactants produced by the microbes can also degrade trapped hydrocarbons in the soil.
- Can completely degrade contaminants, not transfer to another medium.
- Ideal for areas where excavation is not feasible due to depth of contamination and/or physical constraints.
- Requires little above-ground equipment.
- Technology has been field-tested with a proven degree of success.
- Meets all evaluation criteria.

DISADVANTAGES

- Relatively high capital and long-term operation/maintenance costs.
- Relatively time- and labor-intensive.
- Limited applicability in clay rich soils.

RISK PROTECTION

- This option could create exposure pathways for maintenance workers installing and servicing the system; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.

TYPICAL PRIMARY SYSTEM COMPONENTS

- Series of nutrient/oxygen injection wells and/or trenches.
- Series of groundwater withdrawal wells.
- Air stripper and/or GAC for groundwater treatment prior to surface discharge or reinfiltration.
- Reinfiltration galleries.
- Nutrient/oxygen supplies.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
IN SITU BIOREMEDIATION
Page 3 of 4

LIMITING FACTORS

- Method less effective in low-permeability soils due to reduced capacity for reinfiltration and difficulty in delivering nutrients.
- Hydraulic conductivity could be reduced by chemical alteration and subsequent swelling of clay particles in the subsurface.
- Chemical reactions between nutrients and compounds in the soil may precipitate new compounds, reducing subsurface permeability.

RELATIVE EFFECTIVENESS	Low	**Moderate**	High
RELATIVE COST	Low	Moderate	**High**
RELATIVE TIME LINE	Short	**Moderate**	Long

ADDITIONAL COMMENTS

- Effectiveness is highly dependent on formation permeability; low hydraulic conductivities commonly associated with clay-rich saprolite limit the potential for successful implementation of this option.
- Limited enhancement of microbiological activity by periodic surface infiltration of nutrients in concert with soil vapor extraction is an alternative to full-scale bioremediation.
- A relatively common modification of this process is to biologically decontaminate extracted groundwater using aboveground treatment and to reinfiltrate this oxygenated, nutrient-rich water to the subsurface to stimulate bacterial growth.

WASTE GENERATION

This option is a unique means of remediation since it promotes the complete degradation of the contaminants rather than their transfer to another medium. Therefore, there are no hazardous wastes produced.

IMPLEMENTABILITY

This option can be considered implementable in both the tankfield area and the railroad siding.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
***IN SITU* BIOREMEDIATION**
Page 4 of 4

APPLICABILITY IN THE TANKFIELD AREA

To determine the applicability of this option in the tankfield area, a series of pilot tests were completed (see Appendix C). These tests suggest that site conditions are conducive for the implementation of bioremediation techniques. Test results indicated the presence of an adequate indigenous microbial population; the soil pH was also in an acceptable range for microbial activity and inorganic nutrient levels were at acceptable levels.

However, a bench-scale bioremediation test (see Appendix D) showed that the introduction of nutrient-enriched solutions into the soil column would cause swelling of clay minerals, severely limiting the permeability of the soil.

APPLICABILITY IN THE RAILROAD SIDING AREA

Pilot tests were also completed in the railroad siding area to determine the applicability of *in situ* bioremediation. These tests included sampling of onsite soil and groundwater for biological parameters. In the railroad siding area, similar results were obtained; the tests showed that acceptable microbial populations, pH, and inorganic nutrient levels exist.

However, the bench-scale test conducted on soils gathered from the tankfield area showed that bioremediation would be infeasible in this area; therefore, bioremediation may be assumed to be infeasible in the railroad siding area.

PASS/FAIL

Although this option is capable of effectively remediating both soil and groundwater impact with little waste generation, the bench testing of undisturbed soil collected from the tankfield area showed that this option is infeasible. Therefore, this option fails this screening for the entire site.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
AIR SPARGING
Page 1 of 2

ALTERNATIVE Air Sparging or *In situ* Stripping

METHOD DESCRIPTION

Air is injected under pressure below the water table, creating transient air pockets in interstitial pore spaces. Absorbed hydrocarbons trapped by water in these pore spaces volatilize and are transported to the vadose zone to be evacuated by the traditional vent system.

USEFUL LIFE OF THIS ALTERNATIVE

When properly designed and installed, the life of a sparging system will last for the duration of the remediation. The only portion of the system prone to failure is the compressor. Generally a compressor has a life expectancy of approximately 3 years.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

The operation and maintenance requirements for a sparging system are minimal. Generally weekly visits are required to check for proper system operation and to make necessary adjustments.

ADVANTAGES

- Extends usefulness of venting program by venting contaminants from the saturated zone.
- Relatively low cost.
- Relatively non-destructive.
- Air injection increases biologic degradation of contaminants.

DISADVANTAGES

- Less effective in low permeability formations such as this site.
- Does not address contamination in the unsaturated zone.
- Potential to fail due to permeability limitation at this site.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
AIR SPARGING
Page 2 of 2

RISK PROTECTION

- This option could create exposure pathways for maintenance workers installing and servicing the system; adherence to a health and safety plan, which would be completed specifically for this job, will eliminate these health risks.
- This option could create additional health risks by inducing the movement of impacted groundwater into unimpacted areas.

TYPICAL PRIMARY SYSTEM COMPONENTS

- Air injection wells and compressor.
- Vapor extraction wells and vacuum blower.
- Test probe wells for pressure influence testing.

LIMITING FACTORS

- Subsurface geologic barriers.
- Shallow depth to bedrock.
- Potential for vapor/dissolved migration due to system malfunction (over pressure).

RELATIVE EFFECTIVENESS	Low	**Moderate**	High
RELATIVE COST	Low	**Moderate**	High
RELATIVE TIME LINE	**Short**	Moderate	Long

PASS/FAIL

All testing completed to date at this site has shown that soil permeability in the tank field area is slow and permeability in the railroad siding area is extremely slow. This permeability consideration automatically limits the usefulness of sparging.

Attempts to sparge in low permeability formations can cause groundwater mounding above the sparge point, potentially impacting clean material and can also push impacted groundwater into unimpacted areas.

For these reasons, sparging is not considered to be a beneficial option for remediation in either impacted area of this site, and fails these screening criteria.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
BIOLOGIC ENHANCEMENT BY SOIL VENTING
Page 1 of 4

ALTERNATIVE Biological Enhancement by Soil Venting (Bioventing)

METHOD DESCRIPTION

This process involves the enhancement of natural biologic activity in soils, through venting, to treat hydrocarbon contamination. The process involves forced aeration by air injection and/or withdrawal to stimulate biological degradation of volatile and semi-volatile organic compounds. The system may be augmented with nutrient/oxygen injection wells, trenches, or an infiltration gallery.

USEFUL LIFE OF THIS ALTERNATIVE

When properly designed and installed, the life of a biological soil venting system will last for the duration of the remediation. The main portion of the system prone to failure is the air compressor. Generally, a compressor has a life expectancy of approximately 3 years.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

All system components, including air injection or extraction wells, vacuum blower or air compressor, passive inlet wells (if present), vapor treatment (if necessary) and nutrient delivery equipment (if necessary) must be checked weekly.

Performance parameters must be monitored, including vapor concentration; airflow rates; subsurface respiration rates (oxygen consumption and carbon dioxide production); soil contaminant concentration; microbial population; soil pH; soil moisture, and soil nutrient levels.

Maintenance can be completed by a technician; however, special training is required.

ADVANTAGES

- Increased efficiency of bioremediation and contaminant volatilization.
- Relatively non-destructive.
- Relatively short duration; long-term O&M costs should be limited.
- Addresses contamination in both the saturated and unsaturated zones.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
BIOLOGIC ENHANCEMENT BY SOIL VENTING

- Can reduce or eliminate separate-phase product on the water table and reduce the levels of dissolved hydrocarbons in the groundwater.

DISADVANTAGES

- Relatively high capital cost.
- Soil venting off-gas can be expensive to treat.
- May cause coliform bacteria blooms in septic systems, creating a potential for bacteriological contamination of local groundwater supplies.
- Technology is relatively new; effectiveness has not been proven for a wide range of site-specific conditions.
- Has limited application in saturated zone and, therefore, may not be suitable in areas where contaminants have advanced vertically into the saturated zone or where the water table is shallow.

RISK PROTECTION

- This option could create exposure pathways for maintenance workers installing and servicing the system; adherence to a health and safety plan, which would be completed specifically for this job would eliminate these health risks.
- If carbon is used as a means to treat effluent air from the extraction system, all saturated carbon would need to be disposed of as a hazardous waste. This transfers impact from one media to another, potentially creating a health hazard and exposure pathway.

TYPICAL PRIMARY SYSTEM COMPONENTS

- Series of air injection and/or withdrawal wells installed to depths just above water table.
- Series of nutrient/oxygen injection wells and/or trenches.
- Nutrient/oxygen supplies.
- Condensation vessel to remove water from vapor stream prior to treatment.
- Vapor-phase treatment system; most commonly, carbon adsorption for low-flow systems or catalytic oxidation for high-flow systems.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
BIOLOGIC ENHANCEMENT BY SOIL VENTING

LIMITING FACTORS

- Method is less effective in low-permeability soil, such as fine-grained, clay- or silt-rich soils, due to reduced subsurface air flow and difficulty in delivering nutrients.
- Method effectiveness is reduced in high-moisture soils due to tendency of water particles to interfere with volatilization process.
- Effectiveness on longer-chain, low mobility hydrocarbons is uncertain.

RELATIVE EFFECTIVENESS	Low	**Moderate**	High
RELATIVE COST	Low	Moderate	**High**
RELATIVE TIME LINE	Short	**Moderate**	Long

ADDITIONAL COMMENTS

Effectiveness is dependent on the permeability of the formation.

WASTE GENERATION

As with bioremediation, this option promotes complete degradation of organic contaminants rather than their transfer to another medium. However, the process also extracts vapors from the subsurface, which may require the addition of carbon treatment prior to effluent air discharge. High-concentration vapors can be treated by either oxidation units or a thermal destruction unit; then they can be treated with granular activated carbon. Since carbon will become saturated with volatile organics over time, the spent carbon from these units must be disposed of as a hazardous waste. The rate at which carbon becomes spent is proportional to the concentration of volatile in extracted air and the air flowrate.

IMPLEMENTABILITY

This option can be considered implementable in both the tankfield area and the railroad siding.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
BIOLOGIC ENHANCEMENT BY SOIL VENTING
Page 4 of 4

APPLICABILITY IN THE TANKFIELD AREA

Pilot tests completed for soil venting and *in situ* bioremediation feasibility testing were combined. As noted in the soil venting section, this test showed that a high-vacuum extraction unit was capable of producing an induced vacuum of approximately 200 inches of water, and that a radius of influence of approximately 25 to 38 feet could be achieved. The test also showed that after two hours of extraction, volatile organic concentrations in air were detected at 530 ppm (as recorded with an organic vapor monitor) at a lower explosive limit (LEL) of 13%. The results of this study is included in Appendix B.

The *in situ* bioremediation test indicated the presence of an adequate indigenous microbial population, that the soil pH was in an acceptable range for microbial activity, and that inorganic nutrient levels were at acceptable levels. The complete results of this test are included in Appendix C. However, a bench-scale bioremediation test showed that the introduction of nutrient-enriched solutions into the soil column would cause swelling of clay minerals, severely reducing the permeability of the soil. Thus, no nutrient solutions could be added to the soils to further stimulate biodegradation.

Bioventing can be considered an option only if used without the addition of soil nutrients. This type of system is similar to a vapor extraction system and also has the potential to generate waste (spent carbon).

APPLICABILITY IN THE RAILROAD SIDING AREA

Analysis for biological parameters and microbial populations showed that biodegradation could be effective at the railroad siding.

PASS/FAIL

Bioventing can be considered an option for both areas, only if used without the addition of soil nutrients. This type of system is similar to a vapor extraction system and also has the potential to generate waste (spent carbon).

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

ON-SITE INCINERATION

Page 1 of 3

ALTERNATIVE On-Site Incineration

METHOD DESCRIPTION

Excavation and on-site incineration of contaminated soil followed by replacement of treated soil into the excavated area.

USEFUL LIFE OF THIS ALTERNATIVE

Not applicable.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

During the actual soil removal and incineration process, all operations must be continuously overseen.

ADVANTAGES

- Technology has been proven effective.
- Relatively short duration required.
- Active, not passive, treatment option.
- Anticipated high percentage of hydrocarbon removal.

DISADVANTAGES

- Relatively high cost.
- Does not address contaminants in the saturated zone.
- Large staging area required for unit operation.
- Twenty-percent volume reduction of soils will require addition of clean backfill to accomplish site restoration.
- Possible difficulties in excavating materials of varying hardness and resistance.
- Saturated soils must be mixed in equal portions with fly ash to burn, increasing incineration cost.
- Highly destructive to local terrain.
- Soils would be classified as hazardous waste upon excavation.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
ON-SITE INCINERATION
Page 2 of 3

RISK PROTECTION

- This option could create exposure pathways for maintenance workers removing and loading soil; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.
- If air treatment were not installed on the incinerator, gases coming from the incinerator exhaust could create a potential health hazard.
- If carbon is used as a means to treat exhaust gases from the incineration unit, all saturated carbon would need to be disposed of as a hazardous waste. This transfers impact from one media to another, potentially creating a health hazard and exposure pathway.

TYPICAL PRIMARY SYSTEM COMPONENTS

- Portable or trailer-mounted incinerator.
- Clean fill material to completely fill excavation to previous grade.
- Excavation equipment appropriate for site-specific conditions (e.g., backhoe, track-mounted excavator, etc.).

LIMITING FACTORS

- Competent bedrock at shallow depth may make excavation more difficult.
- Presence of underground utilities in the area of impact.
- Type of contaminants present; heavier contaminants may migrate below the depth at which this option is useful, depending on the subsurface environment.
- Significant physical obstructions is some of the affected areas.

RELATIVE EFFECTIVENESS	Low	Moderate	**High**
RELATIVE COST	Low	Moderate	**High**
RELATIVE TIME LINE	**Short**	Moderate	Long

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

ON-SITE INCINERATION

Page 3 of 3

ADDITIONAL COMMENTS

Although this option can be considered very effective in a short time frame there are a number of logistical problems which make it unfeasible. Of the more significant shortcomings are the following:

-some of the affected soil in the tankfield and most of the affected material in the railroad siding could not be excavated due to underground utilities or significant physical obstructions.

-much of the material in both areas of concern is below the water table.

-there are significant limitations on locating a staging area at the facility since all of the eastern portion of the property is taken up by the facility complex and much of the western portion of the facility is occupied by a marsh.

PASS/FAIL

This option fails this screening process since it does not sufficiently address limitations to potential risk, and it requires a large staging area which is not available. The total amount of affected soil that could be removed and remediated is also limited.

Because of these factors, soil excavation and incineration is considered to be unfeasible, and will not be considered further.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL EXCAVATION AND REMOVAL
Page 1 of 4

ALTERNATIVE Soil Excavation and Removal

METHOD DESCRIPTION

Excavation of contaminated soils for recycling or disposal at an approved landfill.

USEFUL LIFE OF THIS ALTERNATIVE

Since affected material is removed and replaced with clean material, the useful life of this option is indefinite, assuming that there is no new introduced source of impact.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

There are no maintenance requirements associated with this option.

ADVANTAGES

- High degree of contaminated soil removal is achievable.
- Requires relatively short time frame for implementation.

DISADVANTAGES

- Limited feasibility for removal of contaminated soils at depths greater than 20-30 feet or in competent bedrock.
- Does not directly address contaminants dissolved in groundwater.
- Relatively high cost.
- Highly destructive; significantly affects local site physiography.
- Requires purchasing and importing significant volume of clean soil to restore excavated area.
- Transfer of contaminated media from origin to offsite location.
- Physical obstructions on the site limit soil removal in some locations.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL EXCAVATION AND REMOVAL

RISK PROTECTION

- This option could create exposure pathways for workers removing, loading and transporting the soil; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.
- This option could create additional health risks by moving impacted soil from one location to another.

TYPICAL PRIMARY SYSTEM COMPONENTS

Excavation of contaminated soil with loading equipment and placing the soil onto trucks for transportation to the landfill. The uncontaminated soil profile is segregated and stockpiled for subsequent use as backfill.

LIMITING FACTORS

- Competent bedrock at shallow depth and/or contaminated soil at a depth greater than 20-30 feet.
- Presence of underground utilities.

RELATIVE EFFECTIVENESS	Low	Moderate	**High**
RELATIVE COST	Low	Moderate	**High**
RELATIVE TIME LINE	**Short**	Moderate	Long

ADDITIONAL COMMENTS

The feasibility of this option may be limited due to limitations that nearby landfills have on the volume of contaminated soil that can be accepted.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL EXCAVATION AND REMOVAL

ADDITIONAL COMMENTS (Cont.)

Excavated soil may be regulated as either a listed- or characteristically-hazardous waste. Site history and research conducted during the RFI shows that all known affected soil at this site has been caused by releases of toluene-based reclaimed press solvent. Any media which comes into contact with this solvent as a result of a spill or a release is classified as a hazardous waste (40 CFR 261.30 through 261.33). Therefore, any affected soil removed from the ground at the site would be considered a hazardous waste.

Although disposal of large quantities of contaminated soil at a landfill is a difficult task, soils can also be incinerated at regulated facilities. Although the option to incinerate soil is slightly more expensive than landfilling, the option also involves less long-term liability to the generator and it is much easier to find a facility that will accept larger volumes of soil.

IMPLEMENTABILITY

This option can be implemented in most of the tankfield area but has limited applications in the railroad siding since most of the affected material there is located immediately adjacent to foundations or other permanent structures.

WASTE GENERATION

All excavated soils would be considered waste.

APPLICABILITY IN THE TANKFIELD AREA

Although there are notable drawbacks to this option, including waste generation considerations, cost, and disposal challenges, this option must be considered to be applicable since it is a fast, effective method of remediating soil impact and eliminating continued groundwater impact. The option is applicable in the tankfield area.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

SOIL EXCAVATION AND REMOVAL

Page 4 of 4

APPLICABILITY IN THE RAILROAD SIDING

Due mainly to physical limitations of removing soils in the railroad siding area, this option is not considered as applicable

PASS/FAIL

Soil extraction is not applicable in the railroad siding due to physical limitations.

This option passes for the tankfield area, assuming a waste facility can be found who will accept the quantities of waste generated as a result of removal.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
PUMP-AND-TREAT AND SOIL VAPOR EXTRACTION
Page 1 of 4

ALTERNATIVE Full-scale groundwater pumping and treatment, in conjunction with soil vapor extraction (SVE).

METHOD DESCRIPTION

On-site decontamination of affected groundwater by pumping to the surface, treatment utilizing a variety of methods, and discharge of treated groundwater to a surface stream and/or reinfiltration gallery.

Extraction of volatile and semi-volatile organic compounds from soils within the unsaturated zone by utilizing vertical and/or horizontal vapor extraction wells with optional passive and/or forced air inlet wells to enhance volatilization.

USEFUL LIFE OF THIS ALTERNATIVE

The useful life of the two major components of this system (when used together) is the same as the life of the components when used separately. The useful life of the components being used separately is described in the respective sections on groundwater pumping and treatment, and soil vapor extraction.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

The operation and maintenance requirements for a SVE system are minimal. Weekly visits are typically required to check for proper system operation and to make necessary adjustments. If a GAC unit is added to treat recovered vapors, then the carbon must be changed when it becomes saturated. The rate at which carbon becomes saturated is dependent on the concentration of recovered vapors and the extraction flowrate.

These two options, when used together, must be maintained at least weekly for general system and operational checks and at least monthly for thorough system checks. These check can include items such as cleaning, sampling, and tower repacking, and granular activated carbon changes. Most system maintenance can be completed by a technician. System components are easily available through many suppliers, and are generally not quickly outdated or frequently upgraded.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
PUMP-AND-TREAT AND SOIL VAPOR EXTRACTION
Page 2 of 4

ADVANTAGES

- Addresses contamination within both saturated and unsaturated zones.
- Reasonably non-destructive the properties.
- Cost savings realized due to reduction in required cleanup time line resulting from use of combined technologies.
- Flexible; SVE points can be varied to address specific site areas.

DISADVANTAGES

- Limited volatility of semi-volatile organic compounds may reduce cleanup rate.
- Requires significant amount of drilling/well installation outside the primary area of contamination.
- Method success may be limited by mobility of vapor and fluids through the local subsurface.
- Will likely require vapor treatment from SVE system.

RISK PROTECTION

- This option could create exposure pathways for maintenance workers servicing the system; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.
- If carbon is used as a means to treat effluent air from the stripper or vapor extraction system, all saturated carbon will need to be disposed of as a hazardous waste. This transfers impact from one media to another, potentially creating a health hazard and exposure pathway.

TYPICAL DATA REQUIREMENTS

- Reasonably defined affected area (e.g., soil and groundwater).
- Definition of contaminant types and expected maximum concentrations.
- Assessment of potential transport pathways prior to remediation and those estimated during remediation.
- Hydrogeologic assessment (pump testing and soil vapor extraction testing) to determine optimum pump rate for recovery, capture zone, optimum reinfiltration flow rate (if selected for treated groundwater discharge).
- SVE performance pilot testing.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
PUMP-AND-TREAT AND SOIL VAPOR EXTRACTION
Page 3 of 4

LIMITING FACTORS

- Method less effective in low-permeability soils due to reduced capacity for reinfiltration of treated groundwater, and reduced subsurface air flow (limited radius of vacuum influence).
- SVE effectiveness reduced in high moisture soils due to tendency of water particles to inhibit volatilization.
- Method effectiveness on longer-chain, low mobility hydrocarbons is less pronounced.

TYPICAL PRIMARY SYSTEM COMPONENTS

- One or more on-site recovery wells installed to a sufficient depth below the water table to allow continuous pumping at the calculated optimum rate.
- Series of on-site injection wells, trenches and/or galleries for reinfiltration of treated groundwater (if this discharge method is selected).
- Series of vapor extraction wells installed to depths just above water table.
- Optional series of air injection wells located within soil and groundwater contamination zone.
- One or more vacuum blowers capable of moving a sufficient volume of air to create and maintain a constant vacuum condition.
- Condensation vessel to remove water from vapor stream prior to treatment.
- Vapor-phase treatment system; most commonly, carbon adsorption for low-flow systems or catalytic oxidation or incineration for high-flow systems.

RELATIVE EFFECTIVENESS	Low	Moderate	**High**
RELATIVE COST	Low	**Moderate**	High
RELATIVE TIME LINE	Short	**Moderate**	Long

IMPLEMENTABILITY

This option can be considered implementable for both the railroad siding and the tankfield area.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
PUMP-AND-TREAT AND SOIL VAPOR EXTRACTION

WASTE GENERATION

Treatment of discharges from an air stripper as part of this option may require addition of carbon treatment as both a final polish prior to water discharge and for treatment of offgases from the air stripper or the SVE unit. Since carbon has a useful life, and will become saturated with volatile organics over time, the spent carbon from these units must be disposed of as a hazardous waste. The rate at which carbon becomes spent is proportional to the concentration of volatile in extracted groundwater and air flowrate.

APPLICABILITY TO TANKFIELD AND RAILROAD SIDING AREA

This option has applicability to both the tankfield area and the railroad siding area. More importantly, when these two options are used in conjunction, they can complement the performance of one another through the following processes:

-as groundwater is removed from the area through the pumping system, more affected soil is exposed, which can be treated with the soil vapor extraction system.

-by inducing a vacuum and withdrawing water from the same wells, the SVE system will enhance the water yield at the well.

-also, by inducing air movement through the soil, natural biodegradation is enhanced.

Vapor extraction pilot testing, which including testing to determine if well yield could be enhanced when vacuum was applied to a well, was successful. The results of the pilot tests are included in Appendix A and B of this report.

PASS/FAIL

This option passes all screening criteria, but has the potential to generate waste (spent carbon).

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
PUMP-AND-TREAT AND SOIL DISPOSAL
Page 1 of 5

ALTERNATIVE Full-scale groundwater pumping and treatment, and limited excavation of soil "hot spots".

METHOD DESCRIPTION

On-site decontamination of affected groundwater by pumping to the surface, treatment utilizing a variety of methods, and discharge of treated groundwater to a surface stream.

Excavation of "hot spot" soils for disposal at an approved landfill.

USEFUL LIFE OF THIS ALTERNATIVE

When properly designed and placed, the major components of a groundwater extraction and remediation system, including wells and/or trenches, piping, and the stripper tower can be expected to last for the duration of the project. Pumps and blowers utilized in the system can be anticipated to last from 1.5 to 5 years. However, physical constituents in soil and water can lead to premature deterioration of system components; for example, silt accumulating in trenches and recovery well filter packs can lead to reduced water recovery and increased wear on pumping components. Adverse water quality conditions, such as high contents of dissolved metals and salts, can cause mineral precipitation and build-up inside of pipes and stripper towers, which can eventually hinder the operation of the system.

The useful life of soil disposal is not applicable.

FREQUENCY AND COMPLEXITY OF MAINTENANCE

Pump-and-treat systems must be maintained at least weekly for general system and operational checks and at least monthly for thorough system checks. These check can include items such as, cleaning, sampling, and tower repacking and granular activated carbon changes. Most system maintenance can be completed by a technician. System components are easily available through many suppliers, and are generally not quickly outdated or frequently upgraded.

There are no maintenance requirements for soil disposal.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

PUMP-AND-TREAT AND SOIL DISPOSAL

Page 2 of 5

ADVANTAGES

- Addresses contamination within the saturated zone and the most highly affected areas within the unsaturated zone.
- Cost savings due to reduction in required cleanup time line and treatment costs resulting from removal of most highly contaminated soil zones.
- Excavated areas may be utilized as primary infiltration galleries for pump and treat operation.

DISADVANTAGES

- Likely to be highly disruptive to site terrain.
- Cost of excavation and disposal significantly escalates capitol costs.
- Excavated soils would be classified as hazardous wastes.
- Limited applicability in the railroad siding due to physical obstructions.

RISK PROTECTION

- This option could create exposure pathways for maintenance workers servicing the system; adherence to a health and safety plan, which would be completed specifically for this job, would eliminate these health risks.
- If carbon is used as a means to treat effluent air from the stripper or vapor extraction system, all saturated carbon would need to be disposed of as a hazardous waste. This transfers impact from one media to another, potentially creating a health hazard and exposure pathway.
- This option could create additional health risks by moving impacted soil from one location to another.

TYPICAL DATA REQUIREMENTS

- Hydrogeologic assessment to determine optimum recovery well(s) location, pump rate for recovery, and capture zone.
- Assessment of potential transport pathways.
- Additional soil quality data needed for soil disposal.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
PUMP-AND-TREAT AND SOIL DISPOSAL

LIMITING FACTORS

- Soil type; pump and treat method less effective in low permeability soils due to reduced hydrogeologic communication and reduced capacity for reinfiltration of treated groundwater.
- Type of contaminants; pump and treat method less effective on longer-chain, low mobility hydrocarbons.

TYPICAL PRIMARY SYSTEM COMPONENTS

- One or more on-site recovery wells installed to a sufficient depth below the static water level to allow continuous pumping at the calculated optimum rate.
- Series of on-site injection wells, trenches and/or reinfiltration galleries for reinfiltration of treated groundwater (if selected).
- Appropriate excavation and transportation equipment.

LIMITING FACTORS

- Soil type; pump and treat method less effective in low permeability soils due to reduced hydrogeologic communication and reduced capacity for reinfiltration of treated groundwater.
- Type of contaminants; pump and treat method less effective on longer-chain, low mobility hydrocarbons.
- Physical obstruction on the surface.

RELATIVE EFFECTIVENESS	Low	**Moderate**	High
RELATIVE COST	Low	**Moderate**	High
RELATIVE TIME LINE	Short	**Moderate**	Long

IMPLEMENTABILITY

This option is very implementable in the tankfield area; however, it has limitations in the railroad siding due to physical obstructions on the surface.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
PUMP-AND-TREAT AND SOIL DISPOSAL

WASTE GENERATION

All excavated soil may be classified as a hazardous waste, and must be disposed of as such by a permitted transporter and disposal facility.

The process of treating water from an air stripper would likely require the addition of carbon treatment as both a final polish prior to water discharge and to treat gases emitted from an air stripper, and gases emitted from the SVE unit. Since carbon has a useful life, and will become saturated with volatile organics over time, the spent carbon from these units must be disposed of as a hazardous waste. The rate at which carbon becomes spent is proportional to the concentration of volatile in extracted groundwater and air flowrate.

APPLICABILITY IN THE TANKFIELD AREA

The existing remedial system installed in the tankfield area is a groundwater pump-and-treat system utilizing one recovery well, capable of producing 3 to 4 gallons per minute, and a stripper tower with GAC carbon polish on the effluent. This system has operated for approximately 5 years. Due to the low permeability of the fine-grained soils in this area, however, the cone of influence created by the single pumping well is sufficient to capture affected groundwater from only a small portion of the entire tankfield area.

Therefore, a modified pump-and-treat system would need to incorporate several additional collection points (e.g., wells) in the tankfield area to expand the area of hydraulic control.

Further, studies have shown that for a typical hydrocarbon spill (specifically gasoline), less than 5 percent of the contaminant mass is dissolved in the groundwater.

APPLICABILITY IN THE RAILROAD SIDING

This option has limited applicability at the railroad siding due to low permeability of those soils (limiting pump-and-treat) and physical obstructions (limiting excavations).

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1 Wilson and Brown, 1989, Groundwater Monitoring Review, Winter 1989, pp. 173-179.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET

PUMP-AND-TREAT AND SOIL DISPOSAL

Page 5 of 5

PASS/FAIL

Groundwater extraction is applicable in the tankfield area, but has the potential to generate waste (spent carbon); remove otherwise immobile groundwater; and continue for an extended duration, due to slow treatment caused by limited groundwater withdrawal potential. For these reasons, this option will not be considered as a stand-alone option for a final determination.

Groundwater extraction is not applicable as a stand-alone remediation option in the railroad siding area since the ability to extract water from recovery wells in the railroad siding is severely limited by low the permeability of the fine-grained soils.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL VAPOR EXTRACTION AND *IN SITU* BIOREMEDIATION
Page 1 of 2

ALTERNATIVE Soil vapor extraction (SVE) and *in situ* bioremediation.

METHOD DESCRIPTION

Extraction of volatile and semi-volatile organic compounds from soils within the unsaturated zone by utilizing vertical and/or horizontal vapor extraction wells with optional passive and/or forced air inlet wells to enhance volatilization.

Introduction of oxygen and nutrients to the subsurface through injection wells, trenches and/or surface infiltration to enhance biodegradation of petroleum hydrocarbons by stimulation of naturally occurring microorganisms.

ADVANTAGES

- Relatively non-destructive.
- Relatively short duration.
- Addresses contamination within both saturated and unsaturated zones.
- Addition of SVE may enhance bioremediation process.
- Reduction or elimination of free product layers on the water table.
- Reduction of dissolved VOC concentrations in groundwater.
- Technology has been field tested and proven effective, even on semi-volatile organic compounds.

DISADVANTAGES

- Requires a significant amount of drilling/well installation outside the primary area of contamination, possibly on private property.
- Potential to be labor intensive, increasing costs.
- Method success may be limited by mobility of vapor and fluids through the local subsurface.
- More stringent air quality regulations may require vapor treatment, increasing costs.
- Spent carbon must be disposed of as a hazardous waste.

TYPICAL DATA REQUIREMENTS

- SVE performance pilot testing.
- Analysis for biodegradation and nutrient optimization.
- Pilot bench test to determine *in situ* peroxide stability, oxygen utilization rates and potential nutrient injection fouling problems within injection and withdrawal wells, trenches and/or galleries.

CORRECTIVE MEASURE ALTERNATIVE DETAIL SHEET
SOIL VAPOR EXTRACTION AND *IN SITU* BIOREMEDIATION
Page 2 of 2

TYPICAL PRIMARY SYSTEM COMPONENTS

- Series of vapor extraction wells installed to depths just above water table.
- Optional series of air injection wells located within soil and groundwater contamination zone.
- One or more vacuum blowers capable of moving a sufficient volume of air to create and maintain a constant vacuum condition.
- Condensation vessel to remove water from vapor stream prior to treatment.
- Vapor-phase treatment system, most commonly carbon adsorption for low-flow systems or catalytic incineration for high-flow systems.

LIMITING FACTORS

- Soil type; method less effective in low permeability soils due to reduced capacity for reinfiltration of treated groundwater, and reduced subsurface air flow (limited radius of vacuum influence).
- Soil moisture content; SVE effectiveness reduced in high moisture soils due to tendency of water particles to inhibit volatilization.
- Type of contaminants; effectiveness on longer-chain, low mobility hydrocarbons is uncertain.

RELATIVE EFFECTIVENESS	Low	Moderate	**High**
RELATIVE COST	Low	**Moderate**	High
RELATIVE TIME LINE	Short	**Moderate**	Long

ADDITIONAL COMMENTS

A bench-scale test was conducted on a representative soil core from this site. The results of this test showed that the introduction of nutrients into the soil would cause clay minerals to swell, severely limiting the ability of the formation to transmit fluid. Because of this factor, bioremediation must be discounted as an option, and fails this screening.

3.4 Summary

The previous corrective measures alternative detail sheets each assess the applicability of various corrective measure alternatives for both the affected areas (tankfield and railroad siding). In some instances, an option passes all major screening criteria for one area but not the other. Tables 3-1 and 3-2 present a summary these options, by area.

In summary, this study has determined that the following corrective measure alternatives are most applicable to the tankfield area:

- site monitoring
- soil excavation and disposal
- combination pump and treat /soil vapor extraction

For the railroad siding area, the following options are the most applicable:

- site monitoring
- combination pump and treat /soil vapor extraction

These options most effectively protect human health and the environment, prohibit future releases, and are technically viable for this site.

In Section 4 of this study, all combinations of these applicable options have been outlined. As was noted in Section 3.1, each of the combination options then factors in the preliminary remediation efforts (tank removal, engineering practices, and updated equipment designs) already undertaken at the facility. Finally, by considering all of these factors, Section 4 further assesses which of the combination options is the most appropriate to be initiated at this site as a corrective measure.

4.0 SELECTION OF THE RECOMMENDED CORRECTIVE MEASURE

4.1 Comparison of Alternatives

The risk assessment and groundwater model performed as part of the RFI demonstrated that no risk exists with current site conditions. The evaluation of corrective action alternatives in Section 3.0 indicated that establishment of a groundwater monitoring program in conjunction with the modifications to engineering practices and equipment design to prohibit future releases in both areas would meet the objectives of the CMS. In addition, although the risk assessment indicated no risk, several corrective action options would shorten the time for monitoring site conditions to confirm the model and risk assessment. After evaluating all criteria presented in Section 3.0, four options were determined to most effectively meet the site objectives. These options, which apply to the tankfield and railroad siding area, include the following:

1. Establishment of a groundwater monitoring program.
2. Establishment of a monitoring program AND soil removal in the tankfield area.
3. Soil removal in the tankfield area AND high-vacuum total phase extraction in the railroad siding area.
4. Pump-and-treat and soil vapor extraction, conducted simultaneously in both affected areas (the feasibility of this alternative assumes that heavily-impacted soils will be removed during already-planned UST excavation and removal).

All options include modifications to engineering practices and equipment design to prohibit future releases in both areas. Quebecor is committed to instituting these engineering changes and has already completed most of them. All options include a groundwater monitoring program, although the scope of the monitoring program is specifically tailored to each option.

A study by Wilson and Brown[1] indicated that for a typical hydrocarbon spill (specifically gasoline) less than 5 percent of the contaminant mass is dissolved in the groundwater. This suggests that soil remediation will address the bulk of a release to soil and groundwater. At the Quebecor facility, the groundwater model has shown the groundwater plume to be stationary due to a balance of groundwater migration and natural biodegradation rates with current conditions. Therefore, remediation of the affected soil will address the major mass component of the chemicals of concern and thereby reduce the time that may be deemed necessary to monitor site conditions.

These four options are conceptually considered to be capable of achieving the goal of corrective measures at the site: protection of human health and the environment surrounding the facility relative to chemicals of concern (CoCs) at the site. Options 2 through 4 are presented to reduce the time frame for monitoring under option 1. Variations between options are discussed in the following paragraphs.

Option 1: Engineering practices and equipment design to prohibit future releases in both areas AND establishment of a groundwater monitoring program

Quebecor has instituted extensive changes in the handling, storage, and operation of the solvent system and its handling, storage, and disposal of hazardous materials in the tankfield area. These changes include, but are not limited to, the following:

- installation of all aboveground solvent transfer lines from the underground storage tank field (November 1993)
- removal of the underground fuel oil tank (Spring 1994)
- replacement of the aboveground fuel oil storage tank (Spring 1994)
- construction of an environmentally-safe bulk ink and solvent loading and off-loading pad (Spring - Summer 1994)
- construction of aboveground solvent storage tanks (Spring - Summer 1994)
- removal of all underground solvent storage tanks (scheduled for September 1994).

Each of the changes will help ensure that the present "no risk" circumstances at the facility are maintained.

The majority of the system changes have already been completed. In combination, they eliminate the potential for undetected subsurface releases and provide for immediate containment and cleanup should any aboveground release occur. Engineering specifications for the aboveground storage tank system are attached in Appendix E.

In the railroad siding area, engineering practices and system modifications were instituted in 1988 - 1989, in response to the surface solvent release of November 1988. These measures, which were instituted to prevent reoccurrence of a similar event, were documented in the incident report submitted to the PADER (included in the USEPA Administrative Record). These measures have been effective and no releases have occurred in this area in the past six years.

This option would also establish a groundwater monitoring program in both areas to monitor the stability of impacted groundwater which has been predicted to be immobile and unrelated to any exposure pathways. This program would include quarterly sampling of perimeter network wells in each area. A perimeter network consists of a selected number of monitoring points located proximal to and downgradient of the affected areas. The detection of any solvent-indicator compound above analytical detection limits in a perimeter well, and confirmed by resampling the well, will result in the re-assessment of the perimeter network program. Site conditions will be reevaluated relative to the risk assessment and groundwater model, and recommendations for further action presented, if necessary.

Option 1 presents a monitoring program which includes quarterly sampling of perimeter network wells, annual sampling of all onsite groundwater monitoring wells, and annual sampling of downgradient domestic wells. Samples will be analyzed for solvent-indicator compounds.

This option meets the CMS objective, generates no waste material, monitors the effectiveness of natural biodegradation, and confirms the results of the groundwater modeling exercise, which indicated no offsite migration of CoCs.

Option 2: Engineering practices and equipment design to prohibit future releases in both areas AND establishment of a monitoring program AND soil removal in the tankfield area

This option includes modifications to engineering practices and equipment design to prohibit future releases in both areas as described in option 1. These changes will help ensure that the present "no risk" circumstances at the facility are maintained. Moreover, the groundwater monitoring program specifications will be the same as in option 1.

This corrective measure option provides the same benefits as option 1 for the railroad siding area, since it establishes the same groundwater monitoring program. However, this option would go a step further in the tankfield area and remove unsaturated soils affected at levels above risk based limits as determined during UST removal. This option would thus reduce potential source areas. However, excavation would generate substantial volumes of soil that would have to be disposed of as hazardous waste. Transportation of these hazardous wastes offsite could present some additional risk to the environment and community.

This option meets the CMS objective by maintaining the current "no risk" conditions at the facility, removes the affected soil in the tankfield area, and monitors the effectiveness of natural biodegradation in the railroad siding area. Soil excavation may generate a significant volume of waste; however, it will be on a one-time basis and will substantially improve soil quality in that area.

Option 3: Engineering practices and equipment design to prohibit future releases in both areas AND soil removal in the tankfield area AND high-vacuum total phase extraction in the railroad siding area

This option includes the same changes discussed in option 1 that will help ensure that the present "no risk" circumstances at the facility are maintained. This option also combines all of the beneficial features of option 2 with high-vacuum total phase extraction in the railroad siding area. This option is thus even more protective of the "no risk" circumstances than option 2.

The groundwater monitoring program for option 3 includes quarterly sampling of perimeter network wells in the tankfield and railroad siding area. The confirmed detection of any solvent-indicator compound in these wells will result in the re-assessment of the recommended corrective action approach.

The groundwater monitoring program for option 3 will also include annual sampling of downgradient domestic supply wells for continued confirmation of the risk assessment.

The railroad siding area would be addressed by high-vacuum total phase extraction. This option would shorten the monitoring period for the railroad area by further reducing the CoCs in soil and groundwater. This system aggressively remediates soil impact while simultaneously increasing water yield for treatment (through vacuum application) and lowering the water table (by dewatering). As the water table is lowered, a larger volume of soil becomes available for vapor extraction.

This option meets the CMS objective by maintaining the current "no risk" conditions at the facility, removes the affected soil in the tankfield area, and remediates the affected soil and groundwater in the railroad siding area. Soil excavation will generate a significant volume of waste; however, it will be on a one-time basis and will substantially improve soil quality in that area. Waste generation volumes from the high-vacuum total phase extraction system in the railroad siding area would be limited to spent air stripper tower packing material, and spent carbon used to polish effluent water from the air stripper and to treat effluent air. This option would be most effective in achieving beneficial results quickly.

Option 4: Engineering practices and equipment design to prohibit future releases in both areas AND pump-and-treat with soil vapor extraction in both the tankfield and railroad siding area

This option includes modifications to engineering practices and equipment design to prohibit future releases in both areas as described in option 1. The groundwater monitoring program is the same as in option 3.

This option addresses soil remediation in both the tankfield and railroad area; however, it does not address soil in the tankfield area as expeditiously as in option 3. Soils of this type, clay-rich with low permeability, can be more effectively addressed by removal than remediation, and thus option 3 is preferred.

This options meets the CMS objective by maintaining the current "no risk" conditions at the facility, generates a smaller volume of waste than option 3, and ranked second in terms of the time needed to achieve beneficial results.

4.2 Recommendation of Corrective Measure

Of the four alternatives presented above, option 3 (modifications in engineering practices and equipment design in both areas, soil removal in the tankfield area, and high-vacuum total phase extraction in the railroad siding area) would be the most effective at meeting the goals of corrective measures at the site. This conclusion is based on the fact that this option protects human health, prohibits future releases, removes affected soils in the tankfield area, and remediates soils in the railroad area, in a reasonable amount of time and with reasonable waste generation for both areas.

4.3 Proposed Remedial System

4.3.1 Remedial System Overview

Tankfield Area

For the tank field area, the remedial option being recommended is soil removal. This option achieves the CMS objectives at the tank field area because (1), soil impacted by CoCs will be removed; (2) all underground storage tanks, which may be a source of CoCs will be removed; (3) no new underground storage tanks or buried piping runs will be reinstalled in the vicinity of the tank field, greatly reducing the chance for additional subsurface releases; (3) the groundwater model completed for the tankfield area shows that no offsite migration of chemicals of concern will occur; (4) and, the risk assessment completed for the site shows that there is no risk associated with chemicals of concern in this area.

Railroad Siding Area

Field testing and all data gathered throughout this CMS indicates that, if active remediation is to be conducted at the railroad siding, high-vacuum total phase extraction is the most effective and efficient option to be used. This option will remediate both soils and groundwater in that area.

With this remediation strategy a vacuum tube is installed in each vapor point, to a depth below the static water table. When vacuum is applied, water is evacuated from the well and pumped to a treatment facility to eliminate upwelling or mounding caused by induced vacuum. As the groundwater is withdrawn to a level below the tube, the same vacuum line is used to vent soils. As additional groundwater is removed by the system, the water table is depressed, creating a larger volume of unsaturated soil that can be treated effectively by the vapor extraction system. The vacuum applied to these points will artificially increase the withdrawal of water, thus increasing the rate that the water table can be depressed, and maximizing the amount of groundwater treated.

Finally, air turnover in the subsurface will add oxygen, which promotes the natural degradation of VOCs by aerobic bacteria. Bioremediation testing conducted at the site indicated that sufficient native bacteria exists in the soils to degrade hydrocarbon compounds. The field testing also suggests that natural biodegradation of affected soils will increase when the amount of available oxygen is increased. Therefore, high-vacuum total phase extraction will further enhance natural degradation of VOCs by aerobic bacteria by providing oxygen through air turnover in the subsurface.

4.3.2 Proposed Remedial System Design

Tankfield Area:

As noted in Section 3.3 of the CMS, the existing USTs and associated piping runs will be removed first, prior to the initiation of any full scale remediation program.

When approval is granted by all applicable agencies, Quebecor would begin a soil excavation program which would entail the removal of all significantly impacted soil in the area located above the static water table. This program would begin by removing clean surface soil (defined for the purpose of this report as any soil with a field-scanned organic vapor monitor [OVM] reading of 10 units or less), and would be stockpiled for reuse. All soils with an OVM reading of greater than 10 units would be stockpiled for disposal.

From data collected during the RFI and CMS studies, it is anticipated that the uppermost two to five feet of soil will be considered clean, and stockpiled. In impacted areas, soils down to a depth of approximately 12 feet would then be removed and stockpiled separately. Soils deeper than 12 feet would not be removed since they would have too high a liquid content to be disposed of without additional mixing with a drying agent. The anticipated areal extent of soil removal is shown in Figure 4-1.

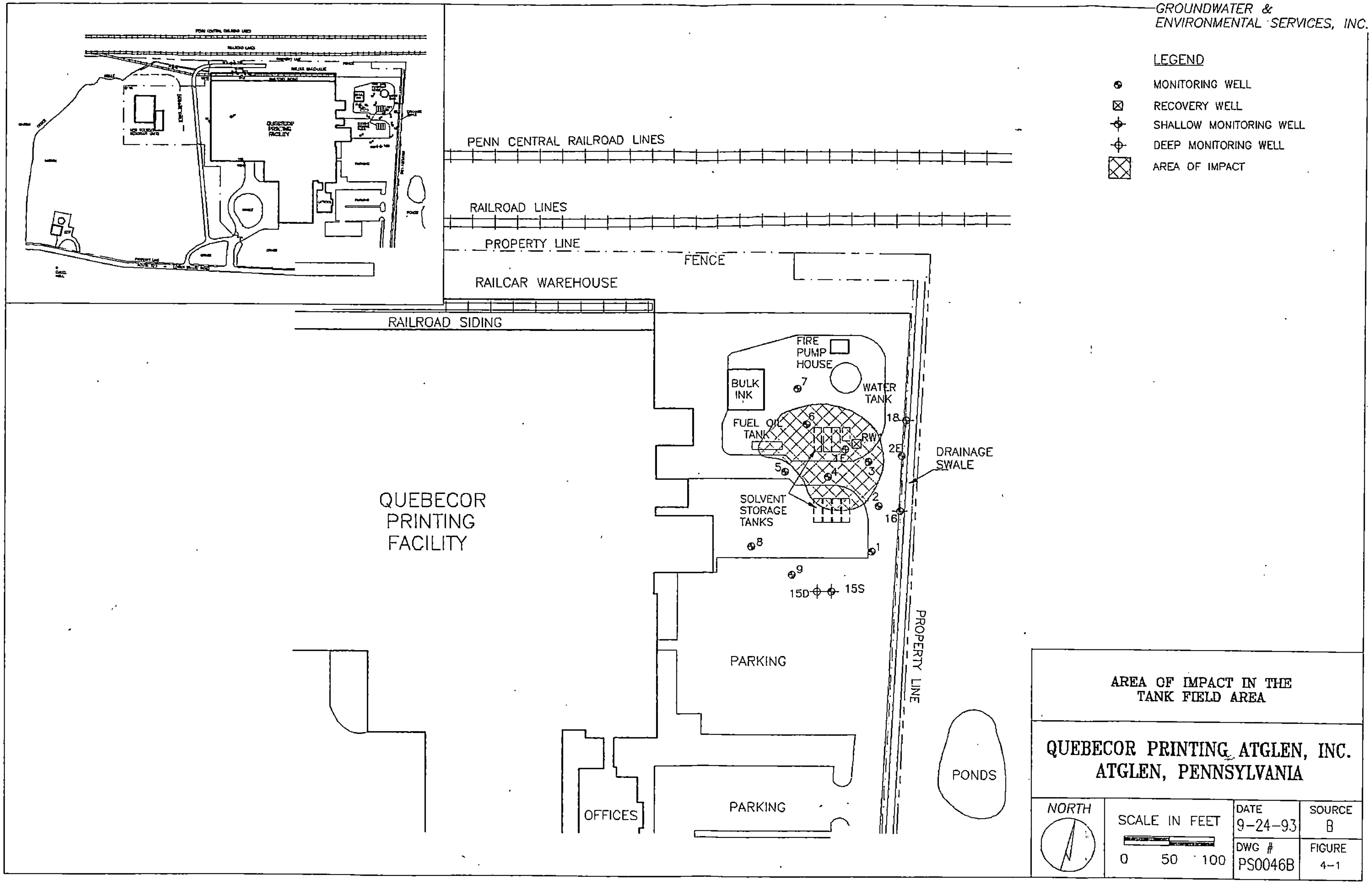
All impacted, stockpiled soils would be placed on plastic sheeting. At the completion of each stockpile, the soil would be covered with additional plastic sheeting, and would be securely anchored. All stockpiled soil would be sampled, per all applicable requirements, manifested, and disposed of at an approved offsite disposal facility. Quebecor would remove all stockpiled soils from the site within 90 days of generation.

Any material needed to fill in excavated material would be composed of borrow-material, graded from areas surrounding the facility. The fill material used would be of a similar soil type as the native soil from this facility.

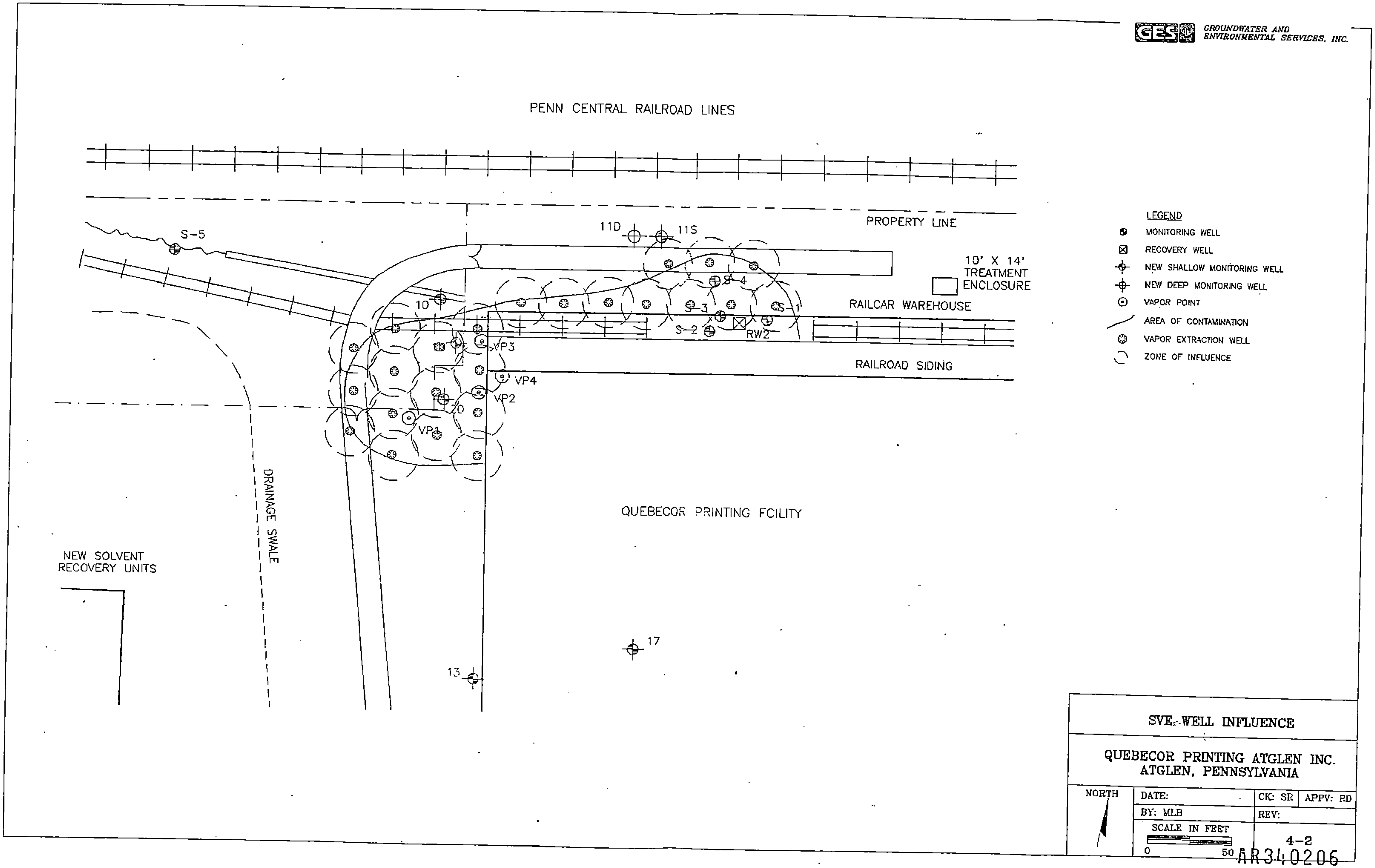
Railroad Siding Area:

The remediation system proposed for this area would consist of approximately 24 soil vapor extraction points manifolded in eight legs of three extraction points each (Figure 4-2). The vapor extraction points would be constructed of 4-inch diameter, 0.040-inch slotted PVC well screen joined to PVC riser (Figure 4-2). A below-grade pitless adapter would be installed near the top of each extraction point so the well can be tied into a manifold system. The vapor extraction points will be installed with a truck-mounted hollow-stem auger drill rig, and will be installed to a depth of approximately 15 feet.

Each extraction point would be capable of removing vapors and water as it accumulates in the well. This process would be controlled by sensors in the well that would open and close solenoid valves as shown on Figure 4-3.


GROUNDWATER &
ENVIRONMENTAL SERVICES, INC.
LEGEND
MONITORING WELL
RECOVERY WELL
SHALLOW MONITORING WELL
DEEP MONITORING WELL
AREA OF IMPACT
PENN CENTRAL RAILROAD LINES
RAILROAD LINES
PROPERTY LINE
FENCE
RAILCAR WAREHOUSE
RAILROAD SIDING
FIRE PUMP HOUSE
BULK INK
WATER TANK
FUEL OIL TANK
RW
DRAINAGE SWALE
SOLVENT STORAGE TANKS
QUEBECOR PRINTING FACILITY
15D
15S
PARKING
PROPERTY LINE
PONDS
OFFICES
PARKING
AREA OF IMPACT IN THE TANK FIELD AREA
QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA
NORTH
SCALE IN FEET
0 50 100
DATE 9-24-93
SOURCE B
DWG # PS0046B
FIGURE 4-1

AR340205


GES GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.
PENN CENTRAL RAILROAD LINES
PROPERTY LINE
S-5
11D
11S
10' X 14' TREATMENT ENCLOSURE
RAILCAR WAREHOUSE
S-4
S-3
S-1
S-2
RW2
10
VP3
VP4
VP2
20
VP1
RAILROAD SIDING
LEGEND
MONITORING WELL
RECOVERY WELL
NEW SHALLOW MONITORING WELL
NEW DEEP MONITORING WELL
VAPOR POINT
AREA OF CONTAMINATION
VAPOR EXTRACTION WELL
ZONE OF INFLUENCE
DRAINAGE SWALE
QUEBECOR PRINTING FCILITY
NEW SOLVENT RECOVERY UNITS
17
13
SVE WELL INFLUENCE
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA
NORTH
DATE:
CK: SR
APPV: RD
BY: MLB
REV:
SCALE IN FEET
0
50
4-2

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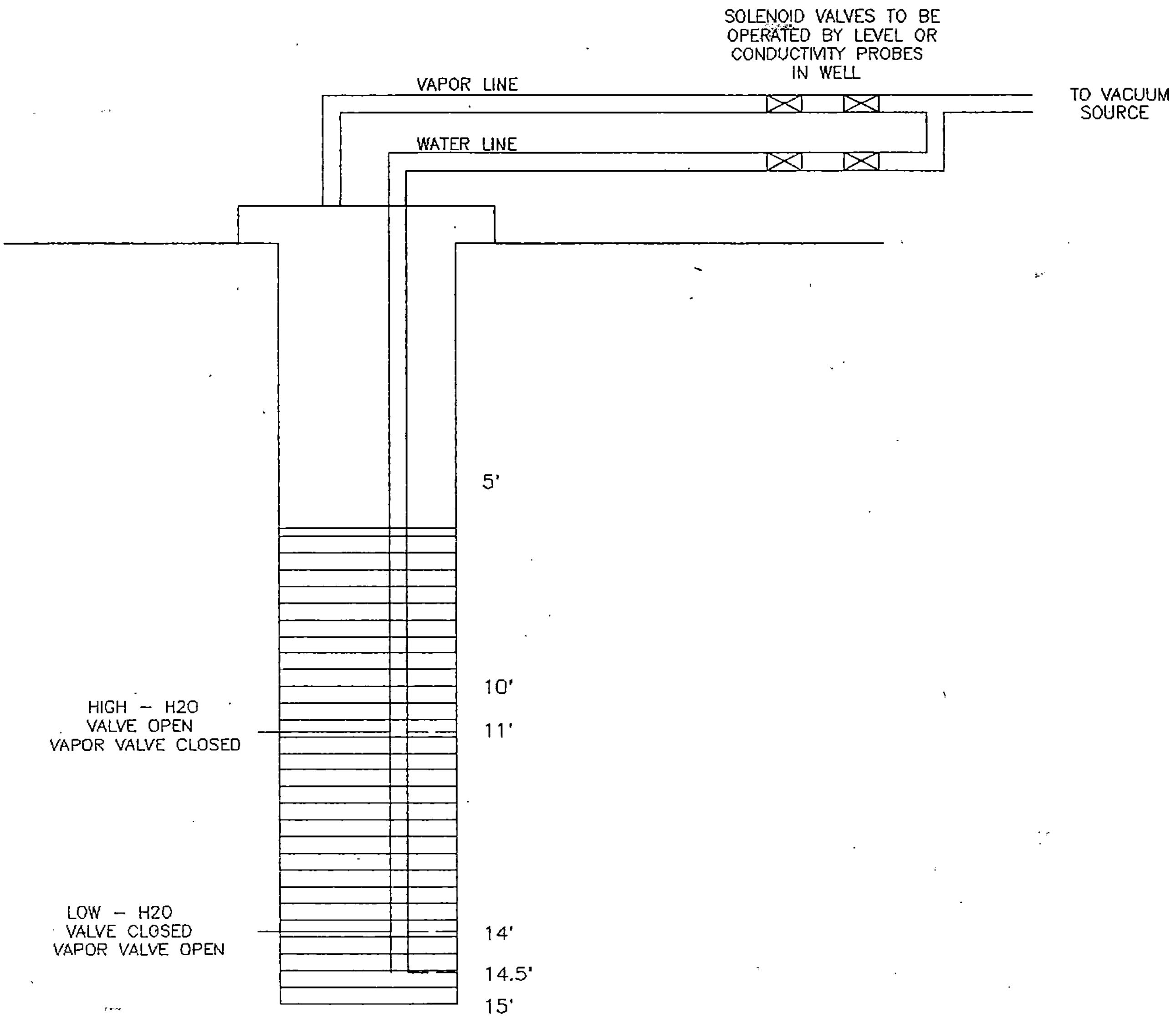
GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.



TYPICAL VAPOR EXTRACTION WELL QUEBECOR PRINTING ATGLEN INC. ATGLEN, PENNSYLVANIA			
NORTH	DATE: 30JUNE94	CK: SR	APPV: RD
NA	BY: MLB	REV:	
	NOT TO SCALE 0	4–3	

A flow diagram for recovered water and vapors is presented on Figure 4-4 and 4-5. The off-gas from the air stripper, along with vapors from the extraction wells, will be treated by the most feasible means depending on concentrations. Treatment options include granular activated carbon, thermal destruction, or catalytic oxidation.

A high-vacuum liquid ring pump would be used to create the vacuum at the vapor extraction points in the railroad siding area. Any water removed from the wells would be pumped to and processed through the water treatment system.

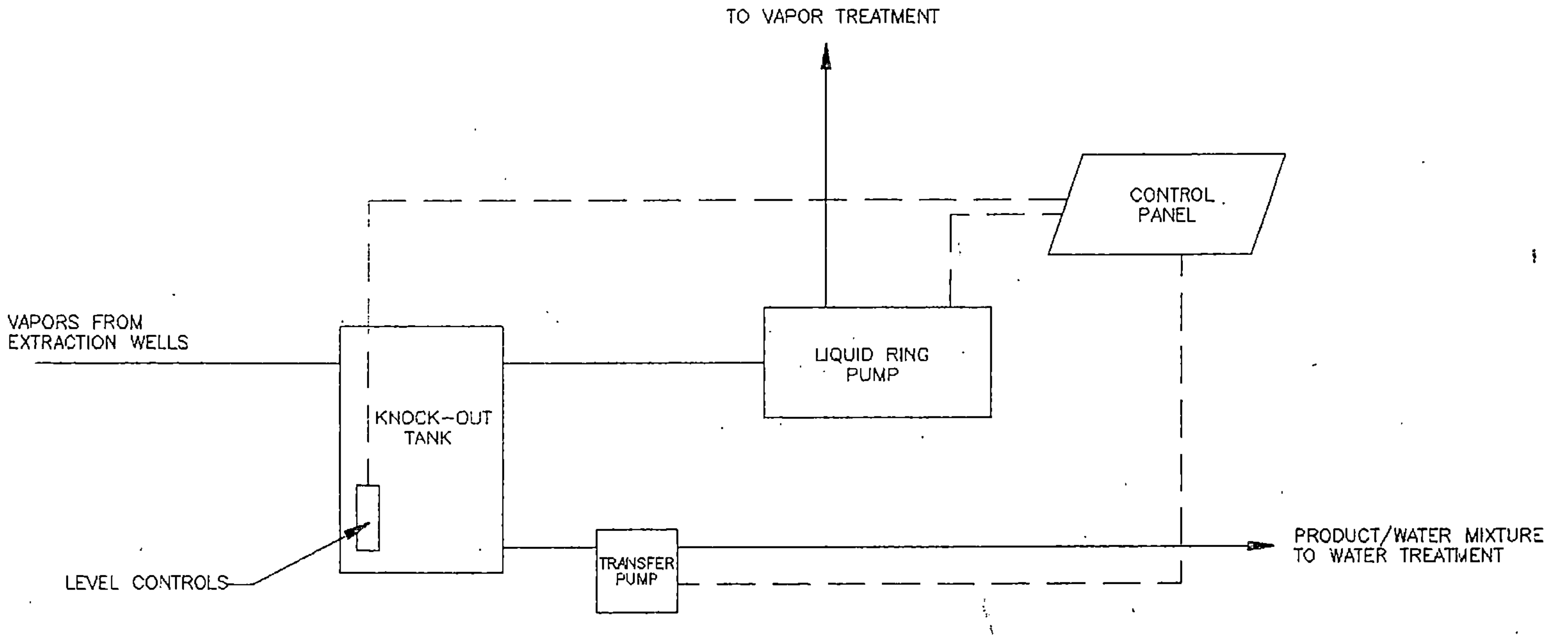
Initially, soil vapors will be withdrawn at high concentrations; these vapors would be treated with a portable thermal destruction unit. The VOC concentrations, lower explosive limits, and the oxygen content of extracted vapors would be monitored during the operation of this system to determine when it would be more cost-effective to switch to a different form of vapor treatment unit, such as catalytic oxidation or granular activated carbon.

All manifold switching equipment, a water knock-out tank, a control panel, a liquid ring pump, and a transfer pump would be located within a 10-foot by 14-foot enclosure, proposed to be installed east of existing wells S-1 and S-4.

4.3.3 Remediation Timeline

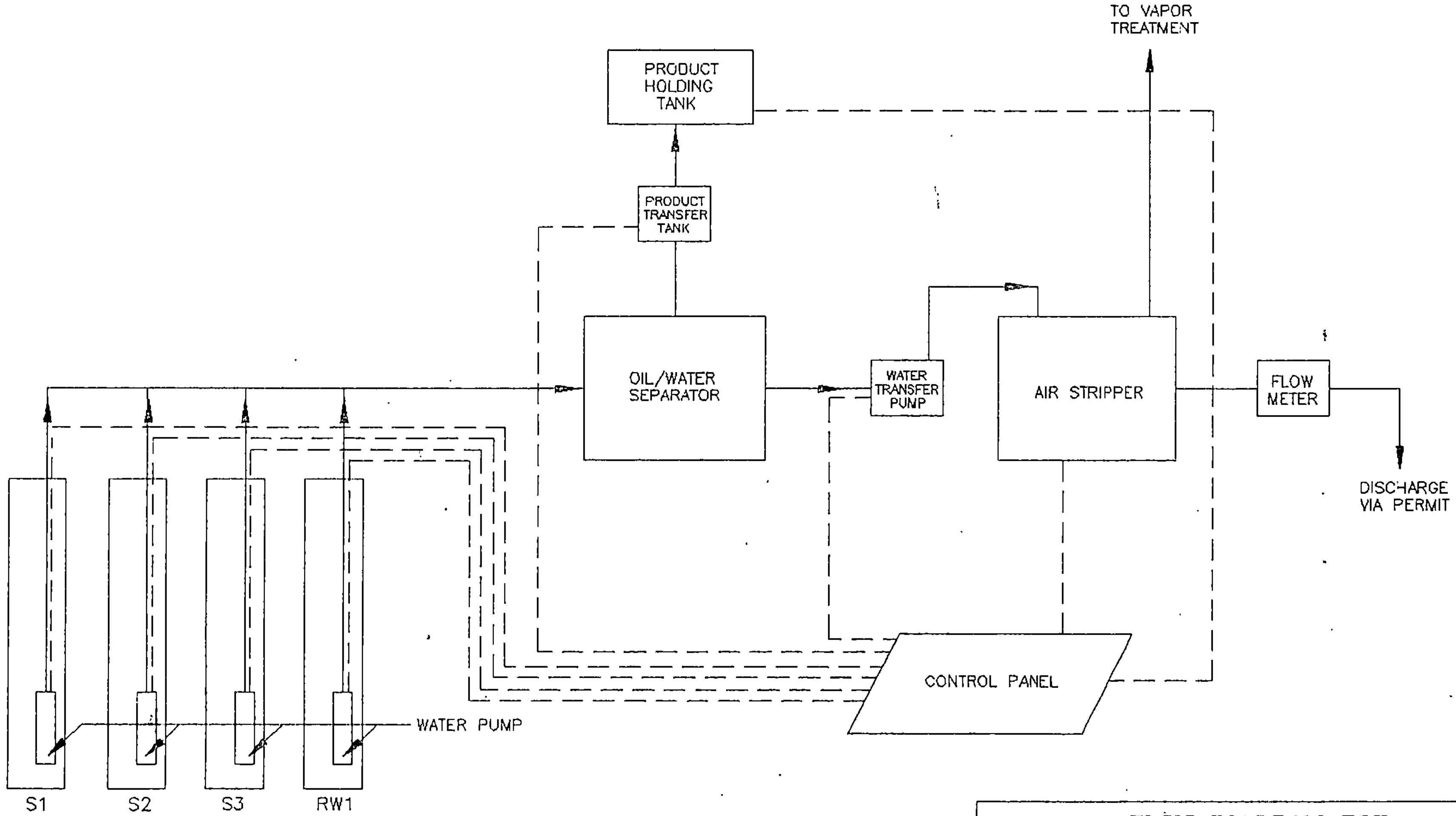
Tankfield Area:

Soil removal from the tankfield area is anticipated to take approximately two to four weeks. In addition, Quebecor will initiate a monitoring program designed to monitor groundwater quality and potential plume migration. This monitoring program is outlined in Section 4.3.4.



FLOW DIAGRAM FOR VAPOR EXTRACTION TYPICAL			
QUEBECOR PRINTING ATGLEN INC. ATGLEN, PENNSYLVANIA			
NORTH	DATE: 6JULY94	CK: SR	APPV: RD
	BY: MLB	REV:	
NA	NOT TO SCALE 0 000	4-4	

GES GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.



FLOW DIAGRAM FOR GROUNDWATER TREATMENT			
QUEBECOR PRINTING ATGLEN INC. ATGLEN, PENNSYLVANIA			
NORTH	DATE: 6JULY94	CK: SR	APPV: RD
	BY: MLB	REV:	
NA	NOT TO SCALE 0 000	4–5	

Railroad Siding Area:

The results of field work have determined that high-vacuum total phase extraction will be effective in further reducing the CoCs in the railroad siding area. Groundwater modeling has shown that no plume migration will occur, and no threat to human health and the environment is present; this system will be installed to remove residual contamination with the overall goal of reducing the required monitoring time.

Quebecor will operate a system which will effectively reduce impact from this area by remediating the soil; however, a component of the proposed high-vacuum total phase extraction system is the recovery of groundwater. Research at numerous sites has recently been completed which finds that complete restorion of groundwater through pump-and-treat techniques is frequently not possible, and may not be an environmentally sound policy once effluent concentration levels have stabilized. More specific research[2] has shown that concentrations of volatile organics frequently will reach an asymptotic equilibrium; continued pumping often has no further or notable effect on these concentrations, even after years of additional treatment. To avoid this problem, Quebecor will employ cutoff criteria which will be used to determine the termination of remediation. These criteria will be as follows:

- An asymptote will be considered achieved, denoting the completion of remediation, if the standard deviation from one year of groundwater monitoring data does not vary by more than 20% and does not exceed 5 parts per million per sample during the quarter; or,

- remediation will be considered achieved if not more that 0.50 pounds of VOCs are recovered per 10,000 gallons of groundwater pumped; or,

- remediation will be considered completed if the average VOC concentrations in influent water for six consecutive months show a 90% or greater reduction in concentration over the average of the first six months of operation; or,

- remediation will be considered completed even if none of the foregoing are satisfied, if Quebecor and the USEPA subsequently agree to another criteria.

4.3.4 Monitoring Program

The following monitoring program is also proposed to verify the "no risk" conditions at the facility:

Tankfield Area

- Monitor well MW-4 annually to gauge improvements in groundwater quality.
- Monitor wells MW-8, MW-16, and MW-15D (part of the perimeter monitoring network) annually to document plume immobility.
- Monitor downgradient domestic well (Gallagher) annually for confirmation of risk assessment.

Railroad Siding Area

- Monitor well MW-10 annually to gauge improvements in groundwater quality.
- Monitor wells MW-12 and MW-14D (part of the perimeter monitoring network) annually to document plume immobility.
- Monitor downgradient domestic well (Engel) annually for confirmation of risk assessment.

- Monitor air stripper influent and effluent waters for parameters dictated by the NPDES permit which would be necessary to operate a treatment system.

- Monitor air stripper and vapor system off-gas concentrations for parameters dictated by the air permit which would be needed to operate a system.

- Re-evaluate soil vapor extraction influent data after levels of VOCs stabilized or dropped below laboratory detection limits. If these data show that VOC levels reach an asymptotic equilibrium (i.e., standard deviation from one year of monitoring data does not vary by more than 20%) or were below laboratory detection limits, approval to discontinue use of the vapor system would be requested from USEPA.

- remediation will be considered completed even if none of the foregoing are satisfied, if Quebecor and the USEPA subsequently agree to another criteria.

4.3.5 Estimated Cost

A cost breakdown for this option is shown in Table 4-1.

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1 Wilson, S.B., and Brown, R.A., 1989, In Situ Bioreclamation: A Cost-Effective Technology to Remediate Subsurface Organic Contamination; Groundwater Monitoring Review, Winter 1989, pp. 173-179.

2 Reaching Contaminant Concentration Asymptote Higher Than Cleanup Goals: Criteria Considerations For Discontinuing Pump and Treat at Three CERCLA Sites; Makdisi, R.S. and Garvason, R.; 1992.

TABLE 4-1
SUMMARY COST ESTIMATE FOR REMEDIATION
QUEBECOR PRINTING ATGLEN INC.

The following estimate details costs for removing impacted soil in the tankfield and initiating a remediation system in the railroad siding area:

Tankfield Area

Assumes removal of 500 cubic yards of soil, disposal as hazardous waste, and backfilling the area with clean fill. Includes establishment of monitoring program as detailed in Section 4.

Total Cost	$ 325,000

Railroad Siding Area

Capital Costs Direct

-Equipment	
-Liquid Ring Pump 20 hp, 3 phase	$ 16,500
-Controls	$ 9,000
-Transfer tanks	$ 3,000
-2 Carbon Vessels (Off Gas Treatment)	$ 9,000
-Treatment Enclosure	$ 7,000
-Air Stripper	$ 7,000
-Oil Water Separator	$ 4,500
-All Other Misc. Materials	$ 13,250
-Subtotal	$ 69,250
-Construction	
-Installation Labor	$ 23,000
-Subcontractors	$ 42,660
-Excavator	
-Electrician	
-Plumbing	
-Subtotal	$ 65,660

Capital Costs Indirect

-Engineering	$ 4,900
-License and Permits	$ 2,000
-Start Up	$ 2,830
-Building and Services	$ 5,000
-20% Contingency	$ 26,980
-Sub Total	$ 41,710
Capital Costs Total	**$ 176,620**

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TABLE 4-1
SUMMARY COST ESTIMATE FOR REMEDIATION
QUEBECOR PRINTING ATGLEN INC.
(Continued)

Annual O&M Costs

Operation and Maintenance (all costs are per year)

-Operating Labor Per Year Including Monitoring Program	$ 16,500
-Maintenance Materials (replacement carbon)	$ 7,500
-Energy	$ 5,000
-Laboratory Fees	$ 2,000
-Disposal Costs (Carbon)	$ 7,500
-Administrative Costs	$ 1,000
-Insurance, Taxes	$ 1,000
-20% Contingency	$ 7,500
Total O&M per year	**$ 48,000**

APPENDIX A

VAPOR EXTRACTION TEST DATA AND ANALYSES
TESTS CONDUCTED ON 25 AND 27 MAY 1994

VAPOR EXTRACTION TESTS
CONDUCTED 25 and 27 MAY 1994

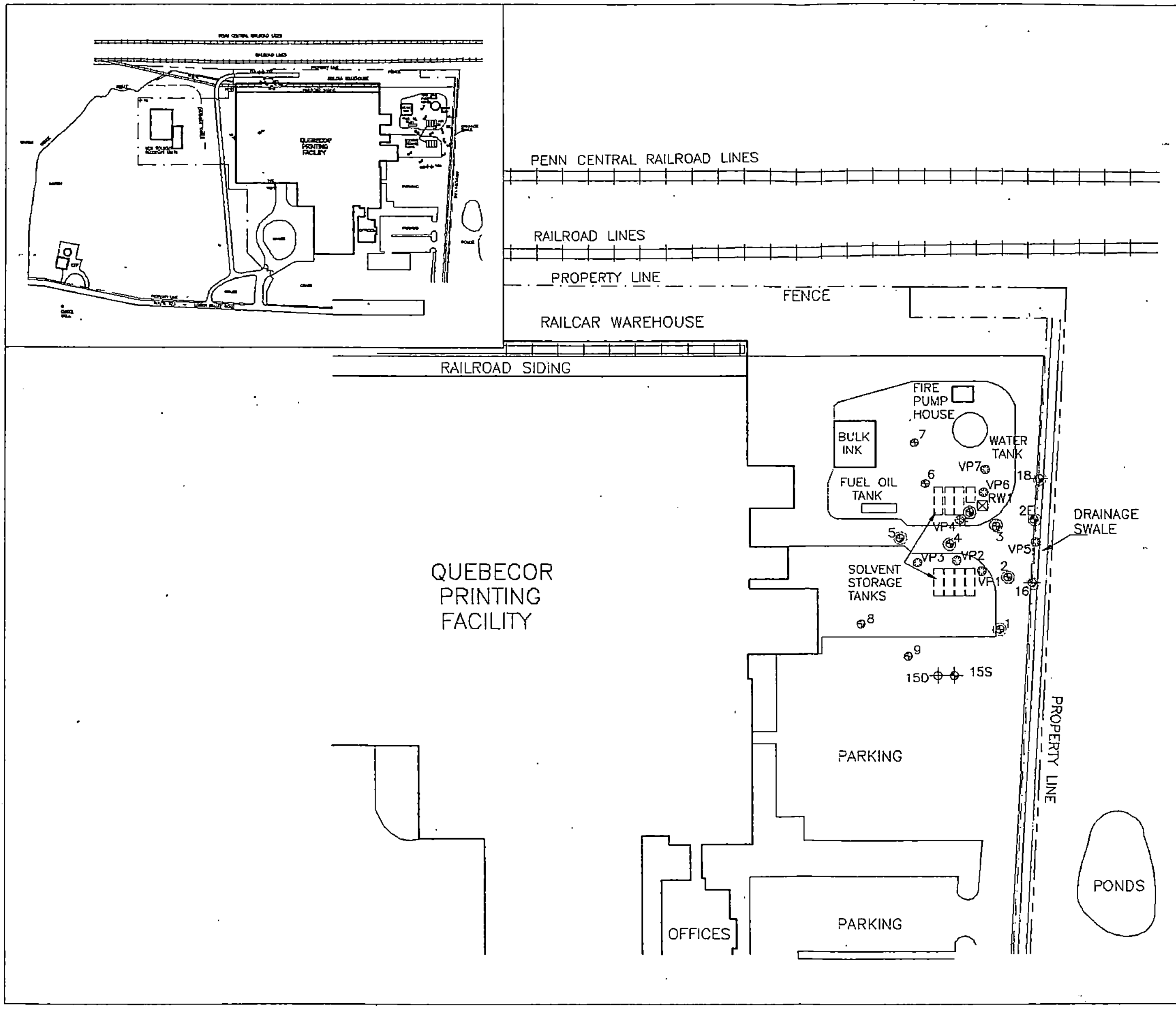
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PA

BACKGROUND

As part of an ongoing Corrective Measures Study (CMS) at the Quebecor facility in Atglen, Pennsylvania, several tests employing high-vacuum extraction were conducted in the tankfield area to determine the feasibility of this technology for remediation and to determine if groundwater withdrawal can be enhanced by high-vacuum extraction. The initial test, completed on 25 May 1994, was performed by extracting vapors simultaneously from wells MW-1E and MW-3. Follow-up tests were performed on 27 May 1994 by extracting vapors individually from the same wells. Wells MW-1E and MW-3 were utilized as extraction wells because they are centrally-located in the tankfield area and their construction allowed installation of adaptors on the wellheads. The well-head adaptors were needed to maintain vacuum in the wells during pumping. Well and vapor monitoring point locations used during the tests are shown in Figure 1.

METHODOLOGY

A vapor extraction and treatment unit (VR unit) manufactured by Vapor Recovery Systems, Inc.® was used to conduct the tests. The VR unit is an internal combustion engine capable of extracting vapors from a designated vapor recovery point at a maximum design air flow rate of 250 cubic feet per minute; the unit is capable of producing a vacuum of up to 300 inches of water.



GROUNDWATER & ENVIRONMENTAL SERVICES, INC.

LEGEND

- MONITORING WELL
- RECOVERY WELL
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- WELL MONITORING POINT
- VAPOR EXTRACTION WELL
- VAPOR MONITORING POINT/ SOIL GAS SAMPLING LOCATION

EXTRACTION AND MONITORING POINTS

VAPOR EXTRACTION TEST
25 & 27 MAY 1994

QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA

NORTH	SCALE IN FEET 0 50 100	DATE 9-24-93	SOURCE B
		DWG # PS0046B	FIGURE 1 APP A

AR340218

Vapors withdrawn from the extraction points are pulled back to the VR unit and destroyed in the internal combustion engine. If hydrocarbon concentrations are high enough, the recovered vapors can be used as the sole source of fuel to run the engine. The system is completely automated and will supply supplemental fuel (propane) when hydrocarbon concentrations in recovered vapors are not sufficient to run the system. The system is capable of removing up to 55 pounds per hour (lbs/hr) of hydrocarbons at a destruction rate of 99.97%.

Soil vacuum induced during the test was monitored with vacuum gauges at existing monitoring wells and temporary vapor monitoring points surrounding the extraction points. The temporary monitoring points were constructed by hand-driving a 1/2-inch diameter steel rod approximately 48 inches below grade. After the rod was removed, a 30-inch long, 1/4-inch diameter copper tube was inserted into the hole. A 1-inch diameter rubber stopper, which slides over the tube, was installed near the top of the copper tube. When the copper tube is inserted into the soil, the rubber stopper acts as a plug and a vacuum seal. Soil pressure and soil gas can also be monitored through this tube.

On Wednesday, 25 May 1994, a high-vacuum extraction pilot test was conducted simultaneously on monitoring wells MW-1E and MW-3 for 8 hours. Both vapor extraction wells were fitted with a specially-designed air-tight cap which allowed a suction tube to be inserted into the well below the water table. When the VR unit was activated, water was withdrawn from the well (by the suction tube) and directed to a knock-out tank. Once the well water was evacuated, the same suction tube was used to withdraw vapors from the surrounding soil. Each time the water column began to recharge in the well, vacuum (by the suction tube) removed the water from the well and continued to draw vapors from the soil. This method of vapor extraction effectively depresses the water column in the well throughout the test and maintains a maximum length of exposed well screen for soil vapor extraction.

Vacuum gauges were deployed on surrounding wells (MW-1, MW-2, MW-2E, MW-4, MW-5, MW-16, MW-18) and vapor monitoring points (VP-1 through VP-7) to monitor remote vacuum influence at each of these points. Separation distances (vapor monitoring point to nearest extraction well) ranged from 13 to 102 feet.

During the pilot test, vacuum readings, air flowrates, and exhaust temperatures at the VR unit were recorded every hour. The volume of water pumped from the extraction wells was also recorded. A Thermo Environmental Instruments® Model 580B photoionization organic vapor meter (OVM) was used to monitor influent volatile organic compounds (VOC) concentrations after the first and second hours of the tests. In addition, an explosimeter was used to monitor the lower explosive limit (LEL) of the influent air stream and an oxygen meter was used to monitor influent oxygen levels after the first and second hours of the pilot test. Induced vacuum was recorded hourly at the monitoring points. Pre-test and post-test depth to water levels were also recorded at the monitoring wells. The tabulated results from the test are included in Table 1.

On Friday, 27 May 1994, follow-up high-vacuum extraction tests were conducted on each extraction well (MW-1E and MW-3) individually. The follow-up tests were performed to check for vacuum "short circuits" in the extraction wells. A vacuum short-circuit exists when air leaks directly from the surface to the vapor extraction point via the well borehole (and associated pathways) so that air movement is not a function of natural soil permeability.

Vacuum readings, air flow rates, and exhaust temperatures at the VR unit were recorded every 30 minutes throughout the follow-up tests. Each extraction well was tested for a minimum of 1.5 hours. Vacuum gauges were deployed on MW-4, VP-2, VP-4, and VP-6. In addition, MW-3 was gauged during the test on MW-1E, and MW-1E and MW-16 were gauged during the test on MW-3. Separation distances for the MW-1E test ranged from 13 to 38 feet; separation distances for the MW-3 test ranged from 28 to 65 feet. Induced vacuums were recorded during the tests at the monitoring points. Follow-up tests results are presented in Table 2.

RESULTS

The results of the pilot test show that high-vacuum extraction had a measurable influence on the surrounding soils. Simultaneous high-vacuum on MW-1E and MW-3 induced a vacuum in monitoring points MW-4 (0.11 inches water after 8 hours) and VP-6 (0.58 inches water after 8 hours). During individual testing, high-vacuum on MW-1E induced vacuums in MW-3 (0.16 inches water after 1.5 hours) and VP-6 (0.10 inches water after 1.5 hours), and high-vacuum on MW-3 induced a vacuum in MW-4 (0.14 inches water after 1.5 hours). Induced vacuum was not observed at the other monitoring points. Vacuum short circuits may account for the absence of induced vacuum at VP-4 (located close to MW-1E) and other monitoring points.

Airflow through the VR unit during the pilot test ranged from 33 to 71 standard cubic feet per minute (scfm). Airflow (when full vacuum was established) ranged from 36 to 44 scfm during the individual test on MW-1E and from 9 to 18 scfm during the individual test on MW-3. The disparity between the air flow values from the individual extraction well tests suggests that the MW-1E test had vacuum short circuits and was not as tight as the vacuum on MW-3.

Influent vapor OVM readings taken after the first and second hour of the pilot test were 610 ppm and 530 ppm, respectively. LEL readings taken after the first and second hours of the pilot test were 11% and 13%, respectively. Influent oxygen concentrations were 18.8% (first hour) and 19.4% (second hour) during the pilot test.

A total of 1,101 gallons of water, or 2.29 gallons per minute (gpm), was pumped from the wells during the pilot test. Since the average combined flow rate from these two wells is approximately 1.0 gpm (estimated from well-purging data), the increase in flow is attributed to the influence of high-vacuum.

Results from the pilot test were used to calculate soil vapor permeability, vapor flow per length of extraction well screen, and vapor extraction well radius of influence. Based on induced vacuum recorded at vapor monitoring points VP-6 and MW-4, and flow volume and vacuum recorded at extraction well MW-1E (the nearest extraction well), calculated soil vapor permeabilities were 1.561 darcys at VP-6 and 1.718 darcys at MW-4. The extraction well flow rate value used in the calculations (47.125 scfm) was based on results from the combined and individual extraction well tests which indicated that flow from MW-1E was approximately 4.3 times that from MW-3. Using the calculated soil vapor permeability values, the radius of influence for MW-1E was calculated to be from 24.98 to 37.96 feet. Calculations used to determine the radius of influence are summarized in Table 1.

CONCLUSIONS

The results of the three high-vacuum extraction tests indicate that this technology is a technically feasible alternative for remediation at the site. The combined well high-vacuum extraction test (25 May 1994) and the individual extraction well follow-up tests (27 May 1994) produced measurable induced vacuums at surrounding vapor monitoring wells. Increased groundwater flow was recorded in the extraction wells during the combined high-vacuum extraction test. Individual follow-up tests suggest that some vacuum short circuits were present at extraction well MW-1E; however, vacuum in MW-1E was sufficient to produce induced vacuums at two vapor monitoring points.

Based on test results, the calculated radius of influence for vapor extraction points in the tank field area is between 24.98 and 37.96 feet. These values are within the range for cost-effective vapor extraction remediation system design.

TABLE 1
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

WELLS TESTED: MW-1E and MW-3

								MONITORING POINTS**	
								VP-6	MW-4
						DISTANCE (ft)*		25 ft.	38 ft.
EXHAUST TEMP. (degrees F)	ELAPSED TIME (hrs.)	VACUUM (inches H2O)	TOTAL LEL (%)	O2 (%)	CO2 (%)	OVM READING (ppm)	FLOW VOLUME (scfm)	INDUCED VACUUM (inches H20)	INDUCED VACUUM (inches H20)
–	START	–	–	–	–	–	–	0.00	0.00
789	1:00	153	13	18.8	–	610	49	0.10	0.41
751	2:00	162	11	19.4	–	530	54	0.11	0.08
690	3:00	175	–	–	–	–	59	0.11	0.20
678	4:00	181	–	–	–	–	54	0.11	0.32
677	5:00	181	–	–	–	–	55	0.10	0.26
622	6:00	196	–	–	–	–	58	0.11	0.22
645	7:00	195	–	–	–	–	60	0.11	0.40
593	8:00	197	–	–	–	–	58	0.11	0.58

LEL = lower explosive limit
OVM = organic vapor meter
O2 = oxygen
CO2 = carbon dioxide

ppm = parts per million
fpm = feet per minute
scfm = standard cubic feet per minute

VP = vapor point
MW = monitoring well
* distance to MW-1E (nearest extraction well)
** induced vacuums were not observed at other test monitoring points

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

	MW-1E	MW-4
Extraction Well Diameter –	2 inches	4 inches
Extraction Well Borehole Diameter –	8 inches	8 inches
Height of Vadose Zone Available for – Extraction or Depth to Water	10 feet	10 feet

PERMEABILITY (k) in darcys

Time/Well	VP-6	MW-4
1:00	1.558	1.714
2:00	1.586	1.740
3:00	1.550	1.701
4:00	1.349	1.482
5:00	1.374	1.508
6:00	1.279	1.404
7:00	1.334	1.466
8:00	1.269	1.396

$$k = \frac{1440 * Pw * Q * u * \ln(Re/Rw)}{19.88 * H * (Pe^2 - Pw^2)}$$

Where:
Q = volumetric flow (CFM) from extraction well
u = viscosity of air (0.018 centipoise)
Re = distance to observation well (feet)
Rw = borehole radius of extraction well (feet)
H = height of vadose zone extracted (feet)
Pe = pressure at observation well (PSI)
Pw = pressure at extraction well (PSI)

TABLE 1 (cont'd)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Calculations for determining vapor permeability (k) and radius of influence of SVE points using equations described by P.C. Johnson et al., Ground Water Monitoring Review, Spring 1990.

Determination of soil permeability (k) in darcys:

The governing equation is:

$$k = \frac{Q * u * \ln(Rw/Ro)}{H * pi * Pw[1-(Po/Pw)^2]}$$

where:
- Q = air flow at the extraction well in cm3/sec
- u = viscosity of air in centipoise (0.018 cp)
- Rw = borehole radius of extraction well in cm
- Ro = distance to observation well in cm
- H = height of unsaturated zone affected by applied vacuum in cm
- Pw = pressure at the extraction well in atmospheres
- Po = pressure at the observation well in atmospheres

The following data are the results of the 25 May 1994 SVE test for VP-6

Q=	47.125 CFM
u =	0.018 Centipoise
Rw =	0.333 feet
Ro =	25 feet
H =	10 feet
Pw (vacuum) =	197 inches-H2O
Po (vacuum) =	0.11 inches-H2O

The following data are converted to units consistent with Johnson's equation

Q=	22240.523 cm3/sec
u =	0.018 Centipoise
Rw =	10.160 cm
Ro =	762.000 cm
H =	304.800 cm
Pw =	0.516 atmospheres
Po =	0.99973 atmospheres

The following data are the results of the 25 May 1994 SVE test for MW-4

Q=	47.125 CFM
u =	0.018 Centipoise
Rw =	0.333 feet
Ro =	38 feet
H =	10 feet
Pw (vacuum) =	197 inches-H2O
Po (vacuum) =	0.58 inches-H2O

The following data are converted to units consistent with Johnson's equation

Q=	22240.523 cm3/sec
u =	0.018 Centipoise
Rw =	10.160 cm
Ro =	1158.240 cm
H =	304.800 cm
Pw =	0.516 atmospheres
Po =	0.99857 atmospheres

Given the above conditions, the permeability of the formation is:

k = 1.27 darcys (VP-6)   **k = 1.40 darcys** (MW-4)

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Determination of flow rate in CFM/ft:

The governing equation is:

$$Q/H = \frac{K * pi * Pw[1-(Po/Pw)^2]}{u * \ln(Rw/Ro)}$$

where:

Q/H = air flow per foot of screen at the extraction well in CFM/ft
u = viscosity of air in centipoise (0.018 cp)
Rw = borehole radius of extraction well in cm
Ro = distance to observation well in cm
Pw = pressure at the extraction well in atmospheres
Po = pressure at the observation well in atmospheres

The following data are the results of the 25 May 1994 SVE test for VP-6

K =	1.27	darcys
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	25	feet
Pw (vacuum) =	197	inches-H2O
Po (vacuum) =	0.11	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.271	darcys
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	762.000	cm
Pw =	0.516	atmospheres
Po =	0.9997	atmospheres

The following data are the results of the 25 May 1994 SVE test for MW-4

K =	1.40	darcys
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	38	feet
Pw (vacuum) =	197	inches-H2O
Po (vacuum) =	0.58	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.398	darcys
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	1158.240	cm
Pw =	0.516	atmospheres
Po =	0.9986	atmospheres

Given the above conditions, the permeability of the formation is:

	VP-6		MW-4	
Q/H =	4.71	CFM/ft	4.71	CFM/ft
Depth to Water (H) feet =	10	feet	10	feet
Flow per Vapor Point is:	47.1	CFM	47.1	CFM

TABLE 1 (cont'd)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Determination of radius of influence in feet:

The governing equation is:

$$k = \frac{Q/H * u * \ln(Rw/Ri)}{pi * Pw[1-(Patm/Pw)^2]}$$

Solving for Ri:

$$Ri = Rw * EXP(-B)$$

where:

$$B = \frac{k * pi * Pw[1-(Patm/Pw)^2]}{Q/H * u}$$

Q/H = Vapor flow per unit length of screen (CFM/ft)

The following data are the expected operating conditions of the SVE system based on data from VP-6

Q/H =	4.71	CFM/ft
u =	0.018	Centipoise
Rw =	0.333	feet
k =	1.27	darcy
Pw =	197	inches-H2O
Po =	0.11	inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	72.968	cm3/sec
u =	0.018	Centipoise
Rw =	10.150	cm
k =	1.27	darcy
Pw =	0.516	atmospheres
Po =	0.99973	atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (MW-1E) is:

Ri = 24.98 feet

The following data are the expected operating conditions of the SVE system based on data from MW-4

Q/H =	4.71	CFM/ft
u =	0.018	Centipoise
Rw =	0.333	feet
k =	1.40	darcy
Pw =	197	inches-H2O
Po =	0.58	inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	72.968	cm3/sec
u =	0.018	Centipoise
Rw =	10.150	cm
k =	1.40	darcy
Pw =	0.516	atmospheres
Po =	0.99857	atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (MW-1E) is:

Ri = 37.96 feet

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

	Distance		Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r16 =	5.883075	179.316126	V(r16) =	0.192633514	1.92
r17 =	6.253080	190.593878	V(r17) =	0.180002485	2.06
r18 =	6.623085	201.871631	V(r18) =	0.168871122	2.19
r19 =	6.993090	213.149383	V(r19) =	0.158990633	2.33
r20 =	7.733100	235.704888	V(r20) =	0.142233313	2.60
r21 =	9.459790	288.334399	V(r21) =	0.113861978	15.16
r22 =	11.186480	340.963910	V(r22) =	0.094684954	18.24
r23 =	12.913170	393.593422	V(r23) =	0.080889511	21.35
r24 =	14.639860	446.222933	V(r24) =	0.070507253	24.49
r25 =	16.366550	498.852444	V(r25) =	0.062421612	27.66
r26 =	18.093240	551.481955	V(r26) =	0.055953110	30.86
r27 =	19.819930	604.111466	V(r27) =	0.050665076	34.08
r28 =	21.546620	656.740978	V(r28) =	0.046264359	37.32
r29 =	23.273310	709.370489	V(r29) =	0.042547004	40.58
r30 =	25.000000	762.000000	V(r30) =	0.039366818	43.86

delX1 (r2 to r19) = 0.370005 feet — Time = 304.70 seconds
delX2(r20 to r30) = 1.726690 feet — 5.30 minutes

delX1 (r2 to r19) = [Rw+(Ri-Rw)*3/10 -Rw]/20
delX2(r20 to r30) = {Ri-[Rw+(Ri-Rw)*3/10}/10

Estimated travel time from the boundary of the influence to extraction well MW-1E

Time = 5.30 minutes

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 25 May 1994

Estimated travel time from the boundary of the influence to extraction well MW-1E

$$V(r) = \frac{- K*[Pw/r*\ln(Rw/Ri)]*[1-(Patm/Pw)^2]}{\{2u*\{1+[1-(Patm/Pw)^2]*\ln(r/Rw)/\ln(Rw/Ri)\}^{0.5}}$$

Estimated effective porosity for air = 0.2

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r1 =	0.333000	10.149840	---	---	---
r2 =	0.703005	21.427592	V(r2) =	2.232600321	0.17
r3 =	1.073010	32.705345	V(r3) =	1.344998139	0.28
r4 =	1.443015	43.983097	V(r4) =	0.950026937	0.39
r5 =	1.813020	55.260850	V(r5) =	0.729203169	0.51
r6 =	2.183025	66.538602	V(r6) =	0.589069467	0.63
r7 =	2.553030	77.816354	V(r7) =	0.492633450	0.75
r8 =	2.923035	89.094107	V(r8) =	0.422415646	0.88
r9 =	3.293040	100.371859	V(r9) =	0.369116199	1.00
r10 =	3.663045	111.649612	V(r10) =	0.327345235	1.13
r11 =	4.033050	122.927364	V(r11) =	0.293769848	1.26
r12 =	4.403055	134.205116	V(r12) =	0.266221533	1.39
r13 =	4.773060	145.482869	V(r13) =	0.243230274	1.52
r14 =	5.143065	156.760621	V(r14) =	0.223765263	1.65
r15 =	5.513070	168.038374	V(r15) =	0.207082870	1.79

Time = 13.34 seconds
0.22 minutes

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TABLE 2
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Tests conducted on 27 May 1994

VAPOR EXTRACTION WELL MW-1E				MONITORING POINTS*	
				VP-6	MW-3
DISTANCE FROM MONITORING POINT TO MW-1E				25 ft.	28 ft.
TEMP. F	ELAPSED TIME (min.)	VACUUM (inches H2O)	FLOW VOLUME (scfm)	INDUCED VACUUM (inches H20)	INDUCED VACUUM (inches H20)
–	START	–	–	–	–
670	15:00	186	37	0.00	0.14
681	30:00	186	39	–	–
–	45:00	–	–	0.08	0.15
669	60:00	189	44	–	–
627	90:00	201	39	0.10	0.16

VAPOR EXTRACTION WELL MW-3				MONITORING POINT*
				MW-4
DISTANCE FROM MONITORING POINT TO MW-3				47 ft.
TEMP. F	ELAPSED TIME (min.)	VACUUM (inches H2O)	FLOW VOLUME (scfm)	INDUCED VACUUM (inches H20)
–	START	–	–	–
504	30:00	166	26	–
569	60:00	196	10	0.14
661	90:00	199	9	0.14

min. = minutes
scfm = standard cubic feet per minute
VP = vapor point
MW = monitoring well
* induced vacuums were not observed at other test monitoring points

APPENDIX B

VAPOR EXTRACTION TEST LETTER REPORT
7 JUNE 1994
(TESTS CONDUCTED ON 4, 5, AND 10 MAY 1994)

Groundwater
& Environmental Services, Inc.

410 Eagleview Boulevard • Suite 110 • Exton, Pennsylvania 19341 • (610) 458-1077 • FAX (610) 458-1081

7 June 1994

Mr. Vernon Butler
Project Coordinator
Region III
United States Environmental Protection Agency
841 Chestnut Building
Philadelphia, Pennsylvania 19107

Re: High-Vacuum Extraction Test Results
Quebecor Printing Atglen Inc.
Corrective Action Consent Order
Docket No. RCRA-3-003IH

Dear Mr. Butler:

The following letter details the results of a series of high-vacuum extraction tests conducted at the above referenced facility on 4 May, 5 May, and 10 May 1994. These tests were performed as part of the Corrective Measures Study being conducted at the site. This letter is being provided, per previous agreement between United States Environmental Protection Agency (USEPA), Quebecor Printing Atglen Inc. (Quebecor), and Groundwater and Environmental Services, Inc. (GES), which stated that the results of pilot tests conducted at the facility would be reported to the USEPA prior to the submittal of the CMS. These test results will also be included with the final CMS.

BACKGROUND

As part of an ongoing remediation study at the Quebecor facility in Atglen, Pennsylvania, GES conducted pilot tests employing high-vacuum extraction to determine the feasibility of this technology as a means of remediation and to determine if groundwater withdrawal can be enhanced by high-vacuum extraction. Tests were conducted by extracting vapors from well RW-2 on 4 May; from well MW-10 on 5 May; and simultaneously from RW-2 and MW-10 on 10 May 1994. Figures 1, 2, and 3 show the well and vapor monitoring point locations used during the tests.

CONCLUSIONS

Based on the results of the three high-vacuum extraction pilot tests that were performed, GES has determined this technology is a technically feasible alternative for remediation at the site. GES is currently in the process of designing a site specific extraction and treatment system for the purpose of cost estimation to determine if vapor extraction is an economically feasible option at this site.

The information presented in this letter will be reiterated in the draft Corrective Measures Study (CMS), scheduled to be submitted to EPA on 31 July 1994. If a high-vacuum extraction system is determined to be the best remedial option for this site, a preliminary design for such a system will also be submitted with the CMS.

Should you have any further questions or comments on this material, please do not hesitate to contact me at this office.

Sincerely,

for:

David Veasey,
Senior Engineer

Enclosures

cc: Diane Potts - Quebecor
Mark A. Sweitzer - GES
Chris Mulry - GES
Daniel Snowdon - PADER
Kevin Martin - GES
Sharon Roberts - GES

GES

TABLE 1
QUEBECOR VR TEST SUMMARY FROM RW2
QUEBECOR PRINTING ATGLEN INC.

TIME	VR VACUUM H2O	AIR FLOW CFM	VACUUM IN INCHES H20			OVM PPM	LEL %
			S1	S2	S4		
15 min	210	45	0	0	0	9.8	2
30 min	204	48	0	0	0	11.4	2
45 min	209	55	0	0	0	16.2	2
60 min	208	55	0	0	0	*	2
90 min	208	57	0	0	0	*	2
120 min	207	58	0	0	0	*	2
150 min	208	60	0	0	0	*	2
180 min	207	61	0.15	0	0	*	2
210 min	207	63	0.62	0.02	0	*	NR
240 min	208	65	0.2	0.025	0	*	NR
270 min	207	65	0.12	0.01	0	*	NR

* OVM stopped functioning
NR - Not Recorded

TABLE 2
QUEBECOR VR TEST SUMMARY FROM MW10
QUEBECOR PRINTING ATGLEN, INC,

TIME	VR VACUUM H2O	AIR FLOW CFM	VACUUM IN INCHES H20		VACUUM AT MONITORING POINTS					LEL %
			MW19	MW20	VP1	VP2	VP3	VP4	OVM ppm	
15 min	192	22	0.05	0.96	0	0	0	0		
30 min	204	25	0.04	1	0	0	0	0	345	3
45 min	222	32	0.04	1.1	0	0	0	0	319	3
60 min	223	27	0.05	1.1	0	0	0	0	311	2
90 min	222	27	0.01	1.1	0	0	0	0	320	2
120 min	226	28	0	0.5	0	0	0	0	256	1
150 min	223	30	0.04	0.9	0	0	0	0.05	277	
180 min	225	30	0	0.9	0	0	0	0	289	1
210 min	223	30	0	0.8	0	0	0	0.02	276	2
240 min	226	33	0	0.8	0	0	0	0.02	205	1

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TABLE 3

V-R TEST SUMMARY FROM RW2 AND MW10

QUBECOR PRINTING ATGLEN INC

TIME	VR VACUUM H20	AIR FLOW CFM	VACUUM IN INCHES H20											OVM (PPM)	O2 (%)	LEL %
			MW19	MW20	VP2	VP3	VP4	VP5	VP6	S1	S2	S3	S4			
30 min	214	82	0.29	0.90	0.0	0.0	0.0	0.0	0.0	0.2		>20	0.0	14	20.5	0
60 min	209	88	0.36	1.15	0.00	0.0	0.0	0.0	0.06	0.2	0	>20	0.0	44	20.4	1
90 min	205	91	0.44	1.70	0.04	0.0	0.0	0.0	0.0	0.52	0.07	>20	0.02	42	20.4	0
120 min	203	93	0.32	1.70	0.04	0.0	0.0	0.0	0.0	0.75	0.08	>20	0.02			0
180 min	199	95	0.30	1.80	0.04	0.0	0.0	0.0	0.02	>1.0	0.06	>20	0.02	37	20.5	
210 min	196	96	0.30	1.00	0.02	0.0	0.0	0.0	0.0	0.15	0.02	>20	0.03	30	20.6	
240 min	195	98	0.44	1.15	0.02	0.0	0.0	0.0	0.02	1.75	0.03	>20	0.03	32	20.6	0
270 min	193	99	0.45	1.20	0.01	0.0	0.0	0.0	0.02	3.1	0.02	>20	0.02	30	20.7	
300 min	191	100	0.52	1.20	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.02	27	20.8	
330 min	189	101	0.68	1.20	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.02	29	20.8	
360 min	187	103	0.76	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	34	20.8	
390 min	185	103	0.74	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	34	20.8	
420 min	184	103	0.79	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	37	20.8	
450 min	182	104	0.93	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02	>20	0.0	50	20.8	
480 min	181	98	0.99	1.10	0.0	0.0	0.0	0.0	0.02	4.5	0.02			50	20.8	

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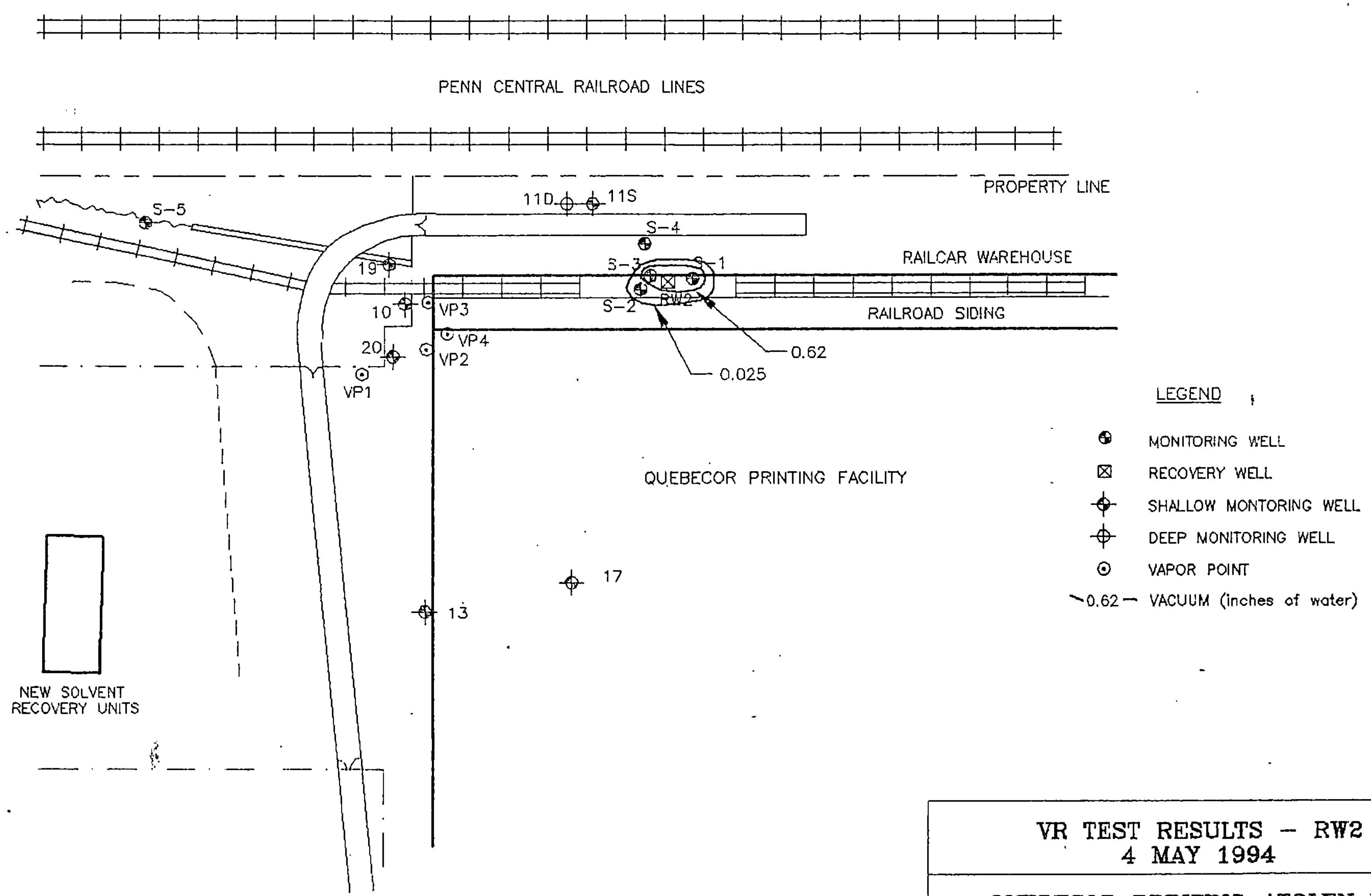
TABLE 4
WATER FLOW RATES
QUEBECOR PRINTING ATGLEN INC.
Summary of results from High-Vacuum Extraction Pilot Tests

DATE	PUMPED WELL (FEET)	FLOW RATE (GPM)	DEPTH TO WATER	WATER LEVEL RISING OR FALLING	ELAPSED PUMPING TIME UNDER VACUUM	VACUUM ON WELL IN H20
4-May-94	RW2	0.33	32.15	Falling	0 min	None
4-May-94	RW2	0.85	NR	Falling	30 min	204
4-May-94	RW2	0.66	NR	Falling	60 min	208
4-May-94	RW2	0.59	NR	Falling	90 min	NR
4-May-94	RW2	0.05	NR	Falling	180 min	207
4-May-94	RW2	0.44	NR	Falling	195 min	207
4-May-94	RW2	0.44	NR	Falling	210 min	207
5-May-94	MW10	0.21	NR	NR	- 20 min	None
5-May-94	MW10	0.2	15.51	Rising	- 10 min	None
5-May-94	MW10	0.22	15.54	Falling	- 5 min	None
5-May-94	MW10	0.75	15.66	Rising	30 min	204
5-May-94	MW10	0.86	13.4	Falling	60 min	223
5-May-94	MW10	0.68	15.46	Rising	90 min	222
5-May-94	MW10	0.67	14.9	Rising	120 min	226
5-May-94	MW10	0.7	14.96	Falling	150 min	223
5-May-94	MW10	0.67	15.6	Rising	180 min	225
5-May-94	MW10	0.67	15.62	Falling	210 min	223
5-May-94	MW10	0.66	15.65	Rising	240 min	226
10-May-94	MW10	0.66	15.2	NR	180 min	196
10-May-94	MW10	0.60	13.65	NR	360 min	185
10-May-94	MW10	0.60	13.75	NR	390 min	184
10-May-94	RW2	0.47	33.27	NR	180 min	196
10-May-94	RW2	0.45	33.4	NR	360 min	185
10-May-94	RW2	0.44	33.0	NR	390 min	184

NR - Not recorded

GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.

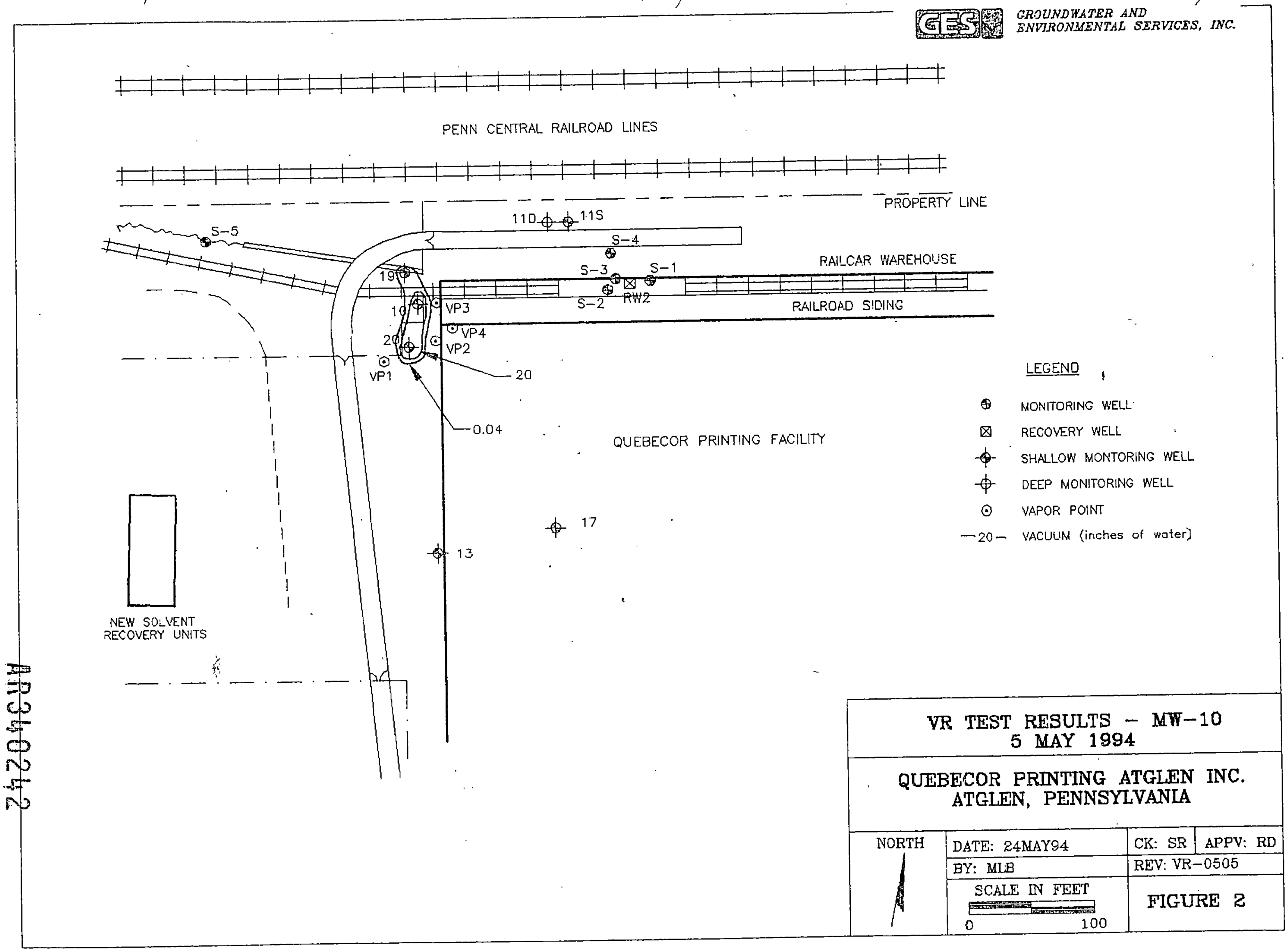


VR TEST RESULTS – RW2
4 MAY 1994

QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

NORTH

DATE: 24MAY94	CK: SR	APPV: RD
BY: MLB	REV: VR-0504	
SCALE IN FEET 0 100	FIGURE 1	


GES
GROUNDWATER AND ENVIRONMENTAL SERVICES, INC.
PENN CENTRAL RAILROAD LINES
PROPERTY LINE
11D
11S
S-5
S-4
S-3
S-1
S-2
RW2
RAILCAR WAREHOUSE
RAILROAD SIDING
19
10
VP3
VP4
20
VP2
VP1
20
0.04
QUEBECOR PRINTING FACILITY
17
13
NEW SOLVENT RECOVERY UNITS
LEGEND
MONITORING WELL
RECOVERY WELL
SHALLOW MONTORING WELL
DEEP MONITORING WELL
VAPOR POINT
—20— VACUUM (inches of water)
VR TEST RESULTS – MW-10
5 MAY 1994
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA
NORTH
DATE: 24MAY94
BY: MLB
CK: SR
APPV: RD
REV: VR-0505
SCALE IN FEET
0
100
FIGURE 2

APPENDIX B

ADDENDUM TO
VAPOR EXTRACTION TEST LETTER REPORT
7 JUNE 1994
(TESTS CONDUCTED ON 4, 5, AND 10 MAY 1994)

TABLE 1
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

ADDENDUM TO VAPOR EXTRACTION LETTER REPORT OF 7 JUNE 1994:
SUMMARY OF CALCULATIONS

Tests conducted 4, 5 and 10 May 1994

Calculations for determining vapor permeability (k) and radius of influence of SVE points using equations described by P.C. Johnson et al, Groundwater Monitoring Review, Spring 1990.

Determination of soil permeability (k) in darcys:

The governing equation is:

$$k = \frac{Q * u * \ln(Rw/Ro)}{H * pi * Pw[1-(Po/Pw)^2]}$$

Where:

Q = air flow at the extraction well in cm3/sec
u = viscosity of air in centipoise (0.018 cp)
Rw = borehole radius of extraction well in cm
Ro = distance to observation well in cm
H = height of unsaturated zone affected by applied vacuum in cm
Pw = pressure at the extraction well in atmospheres
Po = pressure at the observation well in atmospheres

The following data are the results of the 10 May 1994 SVE test on MW-10 for MW-20

Q =	33 CFM
u =	0.018 Centipoise
Rw =	0.333 feet
Ro =	21.5 feet
H =	7 feet
Pw (vacuum) =	181 inches-H2O
Po (vacuum) =	1.1 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q =	15574.266 cm3/sec
u =	0.018 Centipoise
Rw =	10.160 cm
Ro =	655.320 cm
H =	213.360 cm
Pw =	0.555 atmospheres
Po =	0.99730 atmospheres

The following data are the results of the 10 May 1994 SVE test on RW-2 for S-2

Q =	65 CFM
u =	0.018 Centipoise
Rw =	0.500 feet
Ro =	15 feet
H =	10 feet
Pw (vacuum) =	181 inches-H2O
Po (vacuum) =	0.02 inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q =	30676.584 cm3/sec
u =	0.018 Centipoise
Rw =	15.240 cm
Ro =	464.820 cm
H =	304.800 cm
Pw =	0.555 atmospheres
Po =	0.99995 atmospheres

AR340245

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Tests conducted 4, 5 and 10 May 1994

Given the above conditions, the permeability of the formation is:

k =	1.41	darcys	k =	1.58	darcys

Determination of flow rate in CFM/ft:

The governing equation is:

$$Q/H = \frac{K * pi * Pw[1-(Po/Pw)^2]}{u * ln(Rw/Ro)}$$

Where:
Q/H = air flow per foot of screen at the extraction well in CFM/ft
u = viscosity of air in centipoise (0.018 cp)
Rw = borehole radius of extraction well in cm
Ro = distance to observation well in cm
Pw = pressure at the extraction well in atmospheres
Po = pressure at the observation well in atmospheres

The following data are the results of the 10 May 1994 SVE test on MW-10 for MW-20

K =	1.41	darcys
u =	0.018	Centipoise
Rw =	0.333	feet
Ro =	22	feet
Pw (vacuum) =	181	inches-H2O
Po (vacuum) =	1.1	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.411	darcys
u =	0.018	Centipoise
Rw =	10.160	cm
Ro =	655.320	cm
Pw =	0.555	atmospheres
Po =	0.9973	atmospheres

The following data are the results of the 10 May 1994 SVE test on RW-2 for S-2

K =	1.58	darcys
u =	0.018	Centipoise
Rw =	0.500	feet
Ro =	15	feet
Pw (vacuum) =	181	inches-H2O
Po (vacuum) =	0.02	inches-H2O

The following data are converted to units consistent with Johnson's eq.

K =	1.583	darcys
u =	0.018	Centipoise
Rw =	15.240	cm
Ro =	464.820	cm
Pw =	0.555	atmospheres
Po =	1.0000	atmospheres

Given the above conditions, the permeability of the formation is:

Q/H =	4.71	CFM/ft	Q/H =	6.50	CFM/ft
epth to Water (H) feet =	7	feet	Depth to Water (H) feet =	10	feet
Flow per Vapor Point is:	33.0	CFM	Flow per Vapor Point is:	65.0	CFM

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Tests conducted 4, 5 and 10 May 1994

Determination of radius of influence in feet:

The governing equation is:

$$k = \frac{Q/H * u * \ln(Rw/Ri)}{pi * Pw[1-(Patm/Pw)^2]}$$

Solving for Ri:

$$Ri = Rw * EXP(-B)$$

Where:

$$B = \frac{k * pi * Pw[1-(Patm/Pw)^2]}{Q/H * u}$$

Q/H = Vapor flow per unit length of screen (CFM/ft)

The following data are the expected operating conditions of the SVE system based on data from MW-10 and MW-20

Q/H =	4.71	CFM/ft
u =	0.018	Centipoise
Rw =	0.333	feet
k =	1.41	darcy
Pw =	181	inches-H2O
Po =	1.1	inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	72.995	cm3/sec
u =	0.018	Centipoise
Rw =	10.150	cm
k =	1.41	darcy
Pw =	0.555	atmospheres
Po =	0.99730	atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (MW-10) is:

Ri = 21.48 feet

The following data are the expected operating conditions of the SVE system based on data from RW-2 and S-2

Q/H =	6.50	CFM/ft
u =	0.018	Centipoise
Rw =	0.500	feet
k =	1.58	darcy
Pw =	181	inches-H2O
Po =	0.02	inches-H2O

The following data are converted to units consistent with Johnson's eq.

Q/H =	100.645	cm3/sec
u =	0.018	Centipoise
Rw =	15.240	cm
k =	1.58	darcy
Pw =	0.555	atmospheres
Po =	0.99995	atmospheres

Under the above operating conditions, the Radius of Influence at the vapor extraction point (RW-2) is:

Ri = 15.25 feet

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 5 May 1994

Estimated travel time from the boundary of the influence to extraction well MW-10

$$V(r) = \frac{- K*[Pw/r*\ln(Rw/Ri)]*[1-(Patm/Pw)^2]}{\{2u*\{1+[1-(Patm/Pw)^2]*\ln(r/Rw)/\ln(Rw/Ri)\}^{0.5}}$$

Estimated effective porosity for air = 0.2

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r1 =	0.333000	10.149840	---	---	---
r2 =	0.650505	19.827392	V(r2) =	2.532840300	0.13
r3 =	0.968010	29.504945	V(r3) =	1.582202512	0.20
r4 =	1.285515	39.182497	V(r4) =	1.137536034	0.28
r5 =	1.603020	48.860050	V(r5) =	0.882382599	0.36
r6 =	1.920525	58.537602	V(r6) =	0.717835427	0.44
r7 =	2.238030	68.215154	V(r7) =	0.603345274	0.53
r8 =	2.555535	77.892707	V(r8) =	0.519309799	0.61
r9 =	2.873040	87.570259	V(r9) =	0.455129869	0.70
r10 =	3.190545	97.247812	V(r10) =	0.404587863	0.78
r11 =	3.508050	106.925364	V(r11) =	0.363802636	0.87
r12 =	3.825555	116.602916	V(r12) =	0.330229802	0.96
r13 =	4.143060	126.280469	V(r13) =	0.302133788	1.05
r14 =	4.460565	135.958021	V(r14) =	0.278291224	1.14
r15 =	4.778070	145.635574	V(r15) =	0.257815644	1.23

Time = 9.28 seconds
0.15 minutes

GES

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 5 May 1994

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r16 =	5.095575	155.313126	V(r16) =	0.240049409	1.32
r17 =	5.413080	164.990678	V(r17) =	0.224494615	1.41
r18 =	5.730585	174.668231	V(r18) =	0.210767555	1.51
r19 =	6.048090	184.345783	V(r19) =	0.198567879	1.60
r20 =	6.683100	203.700888	V(r20) =	0.177844011	1.79
r21 =	8.164790	248.862799	V(r21) =	0.142659032	10.39
r22 =	9.646480	294.024710	V(r22) =	0.118803903	12.47
r23 =	11.128170	339.186622	V(r23) =	0.101605295	14.58
r24 =	12.609860	384.348533	V(r24) =	0.088640133	16.72
r25 =	14.091550	429.510444	V(r25) =	0.078529554	18.87
r26 =	15.573240	474.672355	V(r26) =	0.070432391	21.04
r27 =	17.054930	519.834266	V(r27) =	0.063806990	23.22
r28 =	18.536620	564.996178	V(r28) =	0.058289137	25.42
r29 =	20.018310	610.158089	V(r29) =	0.053625087	27.63
r30 =	21.500000	655.320000	V(r30) =	0.049632747	29.85

delX1 (r2 to r19) =	0.317505	feet	Time =	207.81	seconds
delX2(r20 to r30) =	1.481690	feet		3.62	minutes

delX1 (r2 to r19) = [Rw+(Ri-Rw)*3/10 -Rw]/20
delX2(r20 to r30) = {Ri-[Rw+(Ri-Rw)*3/10}/10

Estimated travel time from the boundary of the influence to extraction well MW-10

Time = 3.62 minutes

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 4 May 1994

Estimated travel time from the boundary of the influence to extraction well RW-2

$$V(r) = \frac{- K*[Pw/r*\ln(Rw/Ri)]*[1-(Patm/Pw)^2]}{\{2u*\{1+[1-(Patm/Pw)^2]*\ln(r/Rw)/\ln(Rw/Ri)\}^{0.5}}$$

Estimated effective porosity for air = 0.2

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r1 =	0.500000	15.240000	---	---	---
r2 =	0.717500	21.869400	V(r2) =	3.293306096	0.07
r3 =	0.935000	28.498800	V(r3) =	2.365884087	0.09
r4 =	1.152500	35.128200	V(r4) =	1.832044346	0.12
r5 =	1.370000	41.757600	V(r5) =	1.487477977	0.15
r6 =	1.587500	48.387000	V(r6) =	1.247778775	0.17
r7 =	1.805000	55.016400	V(r7) =	1.071964979	0.20
r8 =	2.022500	61.645800	V(r8) =	0.937821531	0.23
r9 =	2.240000	68.275200	V(r9) =	0.832298119	0.26
r10 =	2.457500	74.904600	V(r10) =	0.747242470	0.29
r11 =	2.675000	81.534000	V(r11) =	0.677308592	0.32
r12 =	2.892500	88.163400	V(r12) =	0.618849899	0.35
r13 =	3.110000	94.792800	V(r13) =	0.569296528	0.38
r14 =	3.327500	101.422200	V(r14) =	0.526786989	0.41
r15 =	3.545000	108.051600	V(r15) =	0.489940917	0.44

Time = 3.50 seconds
0.06 minutes

TABLE 1 (cont.)
VAPOR EXTRACTION TEST DATA
CORRECTIVE MEASURES STUDY
QUEBECOR PRINTING ATGLEN INC.
ATGLEN, PENNSYLVANIA

Test conducted 4 May 1994

Distance			Velocity/Effective Porosity		Time/Cell
Location	feet	cm	Location	cm/sec	seconds
r16 =	3.762500	114.681000	V(r16) =	0.457713767	0.48
r17 =	3.980000	121.310400	V(r17) =	0.429301020	0.51
r18 =	4.197500	127.939800	V(r18) =	0.404073302	0.54
r19 =	4.415000	134.569200	V(r19) =	0.381531409	0.57
r20 =	4.850000	147.828000	V(r20) =	0.342976974	0.63
r21 =	5.865000	178.765200	V(r21) =	0.276764875	3.67
r22 =	6.880000	209.702400	V(r22) =	0.231338890	4.39
r23 =	7.895000	240.639600	V(r23) =	0.198326663	5.12
r24 =	8.910000	271.576800	V(r24) =	0.173299912	5.86
r25 =	9.925000	302.514000	V(r25) =	0.153702702	6.60
r26 =	10.940000	333.451200	V(r26) =	0.137959243	7.36
r27 =	11.955000	364.388400	V(r27) =	0.125046560	8.12
r28 =	12.970000	395.325600	V(r28) =	0.114272365	8.88
r29 =	13.985000	426.262800	V(r29) =	0.105151852	9.65
r30 =	15.000000	457.200000	V(r30) =	0.097335646	10.43

delX1 (r2 to r19) = 0.217500 feet   Time = 72.79 seconds
delX2(r20 to r30) = 1.015000 feet   1.27 minutes

delX1 (r2 to r19) = [Rw+(Ri-Rw)*3/10 -Rw]/20
delX2(r20 to r30) = {Ri-[Rw+(Ri-Rw)*3/10}/10

Estimated travel time from the boundary of the influence to extraction well RW-2

Time = 1.27 minutes

APPENDIX C

BIOREMEDIATION ASSESSMENT OF THE
QUEBECOR PRINTING ATGLEN SITE

1.0 INTRODUCTION

The following document discusses the field and laboratory testing that was performed to evaluate the use of bioremediation techniques for the remediation of hydrocarbon contamination at the site. In order to evaluate whether the implementation of bioremediation is appropriate, an evaluation of current site conditions relative to microbiological activity was made. The purpose of performing this initial evaluation was to establish baseline levels and to evaluate whether onsite conditions can be optimized to promote bioremediation. Based on the information currently available, the following phased approach for implementing bioremediation at the site is being considered:

- Use of high vacuum extraction to maximize hydrocarbon contaminant volatilization and free product recovery;
- Operation of vapor extraction system to promote bioventing;
- Monitoring of natural bioremediation for the remediation of any remaining residual contamination.

The collected data will be evaluated to assess the feasibility of the phased approach.

2.0 METHODOLOGIES

In order to efficiently evaluate the feasibility of implementing bioremediation at the site, the following characterization studies were performed:

2.1 Bioremediation Characterization of Groundwater and Soil

Based on the historical data available, groundwater and soil samples were obtained from regions at two designated areas (tankfield and railroad siding) of the site which exhibited low, average and high concentrations of the hydrocarbon contaminants. Table 1 lists the analyses which were performed.

The following monitoring wells were sampled:

Tankfield	Railroad Siding Area
MW-2	S-1
MW-3	S-4
MW-15S	MW-11S

Figures 1 and 2 illustrate the groundwater and soil sampling locations. The samples were collected following GES standard sample collection and Quality Assurance/Quality Control criteria.

2.2 Soil Gas Survey

For bioventing to be successful in stimulating biodegradation, the contaminated areas must be oxygen deficient. In order to evaluate site conditions in regard to this, a soil gas survey was initially performed in the vadose zone soils in one area of interest (tankfield). The soil gas sampling locations for the tankfield are presented in Figure 3. Soil gas sampling probes were installed in the designated area at a depth of approximately 4 feet below ground surface. Parameters that were determined in the soil gas included percent O_2, percent CO_2 and percent methane.

2.3 Bioventing Assessment

Soil gas permeability is the most important site characteristic to evaluate when considering bioventing. The purpose of this evaluation was to determine if the designated areas of the site are permeable enough to allow a minimum of approximately one soil gas exchange per week. This evaluation was done in conjunction with the high vacuum extraction evaluation. Parameters that were determined in the soil gas included percent O_2, percent CO_2 and percent methane.

Initially, a soil gas sampling grid was determined in conjunction with the area designated for vapor extraction testing. Seven soil gas sampling probes were installed at a depth of approximately four feet below ground surface. The soil gas sampling locations for the tankfield are presented in Figure 3. These locations were sampled before the performance of the high vacuum extraction test; midway during the high vacuum extraction test and at selected intervals following the completion of the high vacuum extraction test. This data was evaluated to determine the rate of oxygen consumption during biodegradation of the hydrocarbon contaminants by the indigenous (native) microbial population.

3.0 RESULTS

The results of the analyses that were performed on the collected groundwater and soil samples are summarized in Tables 2 and 3.

3.1 Microbiological Enumerations

This entailed determining the total number of heterotrophic bacteria and specialized groups of bacteria: toluene degraders, xylene degraders and total petroleum hydrocarbon (TPH) degraders in collected groundwater and soil samples.

3.2 Inorganic Groundwater Analyses

Inorganic nutrient analysis (nitrogen, phosphorus, iron and sulfate) and pH were determined to assess background conditions and to evaluate whether nutrient addition or pH adjustment would be required depending on the remediation technology chosen. Iron and sulfate levels were determined to assess background conditions and to evaluate whether site conditions are conducive for natural attenuation..

3.3 Inorganic Soil Analyses

Inorganic nutrient analysis (nitrogen and phosphorus) and soil pH were determined to assess background conditions and to evaluate whether nutrient addition or pH adjustment would be required depending on the remediation technology chosen.

3.4 Organic Analysis

In the groundwater samples, the concentration of total organic carbon (TOC) and benzene, toluene, ethylbenzene and xylenes were determined. In the soil samples, the concentration of benzene, toluene, ethylbenzene and xylenes were determined. This information was used to evaluate background conditions relevant to the potential of implementing bioremediation techniques.

4.0 DISCUSSION

The following is a discussion of the results.

4.1 Microbial Enumerations

Microbial activity in the soil and groundwater was assessed by determining the number of microorganisms present in a given sample. Plate count analysis is one method of determining microbial population numbers. For this procedure, suitable sterile dilutions of the collected samples were pipetted onto petri dishes containing an agar-based growth medium. The petri dishes were then incubated at room temperature for fourteen days until microbial colonies could be visibly detected. Each microbial colony that could be visibly detected is the result of the growth of a single bacterium repeatedly reproducing under optimal growth conditions. After accounting for the dilution factor used, the minimum number of viable bacteria present in a designated sample was determined. The results are reported as colony-forming-units (cfu) per gram of dry-weight (soil) or milliliter (ml) (groundwater). Microbial enumerations from soil samples are corrected for the moisture content of the soil. This method of microbial enumeration does have limitations. There is no single type of agar growth medium that will support the growth of all types of microorganisms. For example, subsurface microorganisms may not grow on agar plates containing high levels of organic carbon such as those used to enumerate wastewater or medical microorganisms. The subsurface microorganisms may only grow when cultured on agar plates containing low levels of organic carbon similar to the concentrations found in their natural environment. Therefore, the results obtained from the plate count analysis are interpreted as the minimum instead of the actual number of viable organisms present in a soil sample.

For the samples collected at the site, plate count enumerations for total heterotrophs, toluene and xylene degraders were performed. Total heterotrophic microorganisms are defined as that group of microorganisms which obtain their energy from the oxidation-reduction reactions of organic compounds and their required carbon from organic carbon. Petroleum hydrocarbon (PHC) biodegradation is the direct result of heterotrophic metabolism where the PHCs serve as a source of carbon and energy for the microorganisms. Enumeration of the total heterotrophic population was determined by spread plating a dilution of an aliquot of sample from each respective area (and matrix) onto a general purpose solid microbial growth medium. All spread plates were done in duplicate. The values reported represent the geometric mean of the duplicate enumerations.

Plate count techniques allow tailoring of the growth media to allow the selection of specific physiological groups of microorganisms. This tailoring allows the determination of the number of microorganisms present in a sample that are capable of metabolizing a specific contaminant of interest. Because of the nature of the hydrocarbon contaminants at this site, the enumeration of toluene and xylene degraders was performed. Enumeration of toluene and xylene degraders was performed by spreading a small sample volume onto an agar growth medium (spread plating) and incubating the plates in an atmosphere saturated with the compound of interest (i.e., toluene or xylene) as the sole source of carbon and energy. All spread plates were done in duplicate. The values reported represent the geometric mean of the duplicate enumerations.

TPH degraders were determined using the Sheen Screen technique. This is a most-probable-number technique. The most probable number (MPN) method is an alternative to plate count methods for enumerating microorganisms. The MPN method employs the use of a liquid culture media as opposed to the solid culture media utilized in the plate count method. For the Sheen Screen MPN method for determining TPH degraders, a petroleum hydrocarbon is employed as the sole carbon and energy source in the growth media. For the soil samples collected at this site, number 2 fuel oil was used as the petroleum hydrocarbon source. The MPN method utilizes statistical analysis and successive dilution (reduction in concentration) of the sample. Replicate dilutions are observed for growth or no-growth after inoculation and incubation of a particular dilution of the sample. If viable micro-organisms are present in the respective dilution of the sample that can use the number 2 fuel oil as the sole source of carbon and energy, growth will occur after the aliquot is introduced into the MPN culture medium.

The observations of growth or no-growth are scored as positive or negative respectively. The pattern of positive or negative scores are used in connection with appropriate statistical tables to obtain the most probable number of viable microorganisms present in a sample.

As summarized in Figures 4 and 5, the data indicate the presence of all categories of microorganisms at all locations sampled at the site over a wide range of toluene and xylene concentrations. This suggests an enrichment of the indigenous microbial community for populations with the metabolic capabilities to degrade toluene and xylene.

4.2 Inorganic Analyses

The most significant inorganic nutrients needed for microbial growth are nitrogen (typically in the form of ammonia) and phosphorus (typically in the form of ortho-phosphate). In general, the levels of inorganic nutrients are within acceptable ranges for bioremediation. Iron and sulfate levels were determined in the groundwater samples because there is evidence that these compound can serve as terminal electron acceptors in the absence of oxygen (anaerobic conditions) for the biodegradation of toluene and xylene. Changes in these levels would be tracked over time to monitor the potential for anaerobic degradation of the hydrocarbon contaminants at the site.

The soil pH can affect the availability and mobility of the contaminants. Soil pH can also be toxic or inhibitory to the microorganisms. The ideal pH range for most microbiological activities is in the range of 6.5 to 8.5. The pH range for the soil and groundwater samples at all locations was within this acceptable range.

4.3 Organic Analyses

Total organic carbon levels in the groundwater samples ranged from 13.65 to 143.40 parts per million (ppm). Toluene levels ranged from less than the minimum detection level (BDL) to 83,000 µg/l. Total xylenes ranged from BDL to 2,900 µg/l. These data indicate that at some locations other organic compounds (many naturally occurring) besides the hydrocarbon contaminants are present. This can have an effect on the rate of biodegradation of the hydrocarbon contaminants as the other organic compounds may be preferentially degraded first before the hydrocarbon contaminants are utilized by the indigenous microorganisms. It is also possible that the presence of the other organic compounds may also stimulate the biodegradation of the hydrocarbon contaminants. In this scenario the same metabolic capabilities that are utilized to degrade the other organic compounds are simultaneously utilized to degrade the hydrocarbon contaminants. During active remediation, the TOC and hydrocarbon contaminant concentrations would be monitored to evaluate the rate of bioremediation progress.

4.4 Soil Gas Survey

The results of the soil gas survey for the seven monitoring points that were installed in the tankfield area are summarized in Table 4. At these locations, the soil gas concentrations of oxygen, carbon dioxide and methane were determined. Only one location, VP-6 indicated a depletion of oxygen levels relative to ambient levels (approximately 20% O_2). VP-6 also had the highest percent CO_2 and percent methane levels relative to the other monitoring points. Interpretation of these data suggests that at the depths and locations that vapor points VP-1, VP-2, VP-3, VP-4, VP-5, and VP-7 were not ideal. These monitoring points were not effectively isolated from influence from the surface, thereby allowing diffusion of oxygen. VP-1, VP-2, VP-4 and VP-6 were installed in known areas of hydrocarbon contamination based on data available from previous investigations. However, the site soils, as well as the distribution of the contaminant are reported to be very heterogeneous, making it possible that the soil gas points were not installed at the optimum depths or locations to monitor oxygen uptake. Only the results obtained from VP-6 were indicative of on-going biological activity (depletion of O_2 and production of CO_2 and methane).

4.5 Bioventing Evaluation

Bioventing is the term used to describe the merger of soil vapor extraction technologies with bioremediation. It is an *in situ* process where aerobic biodegradation of the contaminant(s) is promoted by the movement of air through the soils to increase soil oxygen levels. The addition of oxygen to the soil promotes degradation of the contaminant(s) by the indigenous microbial population.

Whether or not a site is a good candidate for bioventing is based on the results of a field test referred to as an *in situ* respiration test. In this test, fresh air is introduced into the subsurface in a contaminated area via vapor extraction techniques, bringing the levels of oxygen to approximately 21%. The vapor extraction system is then shut off and the rate at which the oxygen is utilized by the indigenous microorganisms is monitored over a 40- to 80- hour monitoring period. Soil gas monitoring points in areas amenable to bioventing will show a significant decline in oxygen over the monitoring period.

The soil gases in all seven monitoring points were monitored to evaluate the oxygen utilization rates at each location. However, as was discussed previously in the soil gas monitoring section, only monitoring point VP-6 had data which is indicative of a successful bioventing application. The results for all monitoring points for the *in situ* respiration test are presented in Table 5. Graphical presentation of the results for vapor point VP-6 are illustrated in Figure 6. Linear regression analysis was used to determine k, the estimated rate of oxygen utilization for VP-6. It was determined to be 0.28% /hr, which is in the range of rates reported by other *in situ* respiration studies (Hinchee, 1993).

5.0 CONCLUSION / RECOMMENDATIONS

The data obtained from this initial bioremediation evaluation at the Quebecor site suggest that site conditions are conducive for the implementation of bioremediation techniques. The microbial enumerations indicated the presence of an adequate indigenous microbial population; the pH was in an acceptable range for microbial activity and inorganic nutrient levels were at acceptable levels.

The soil gas survey and bioventing evaluation suggest that bioventing may be a viable *in situ* remediation technique for the site. However, the results also suggest that there is a potential for 'short-circuiting'.. In order to effectively implement a full-scale remediation system, an additional soil gas survey and *in situ* remediation study may be warranted to insure proper and effective placement of the treatment system components. Performance of this additional study would entail the use of multiple soil gas sampling probes at different depths. This information would allow more effective characterization of the site in regards to the heterogeneities present.

6.0. REFERENCES

Hinchee, R.E,. 1993. Bioventing of Petroleum Hydrocarbons. In In-Situ Bioremediation of Ground Water and Geological Materials: A Review of Technologies. Robert S. Kerr Environmental Research Laboratory. Office of Research and Development. U.S. Environmental Protection Agency. Ada, Oklahoma. 74820. EPA/600/R-93/124.

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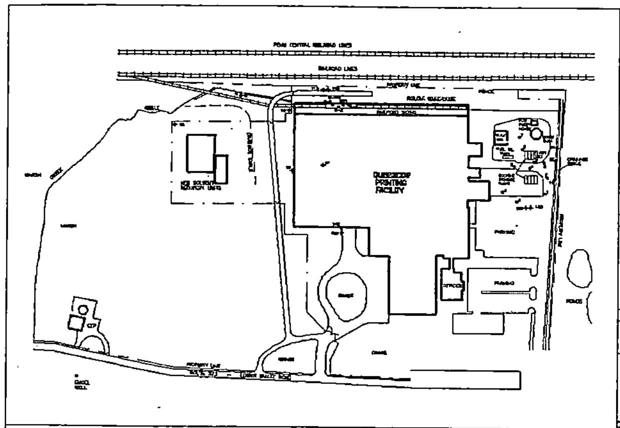

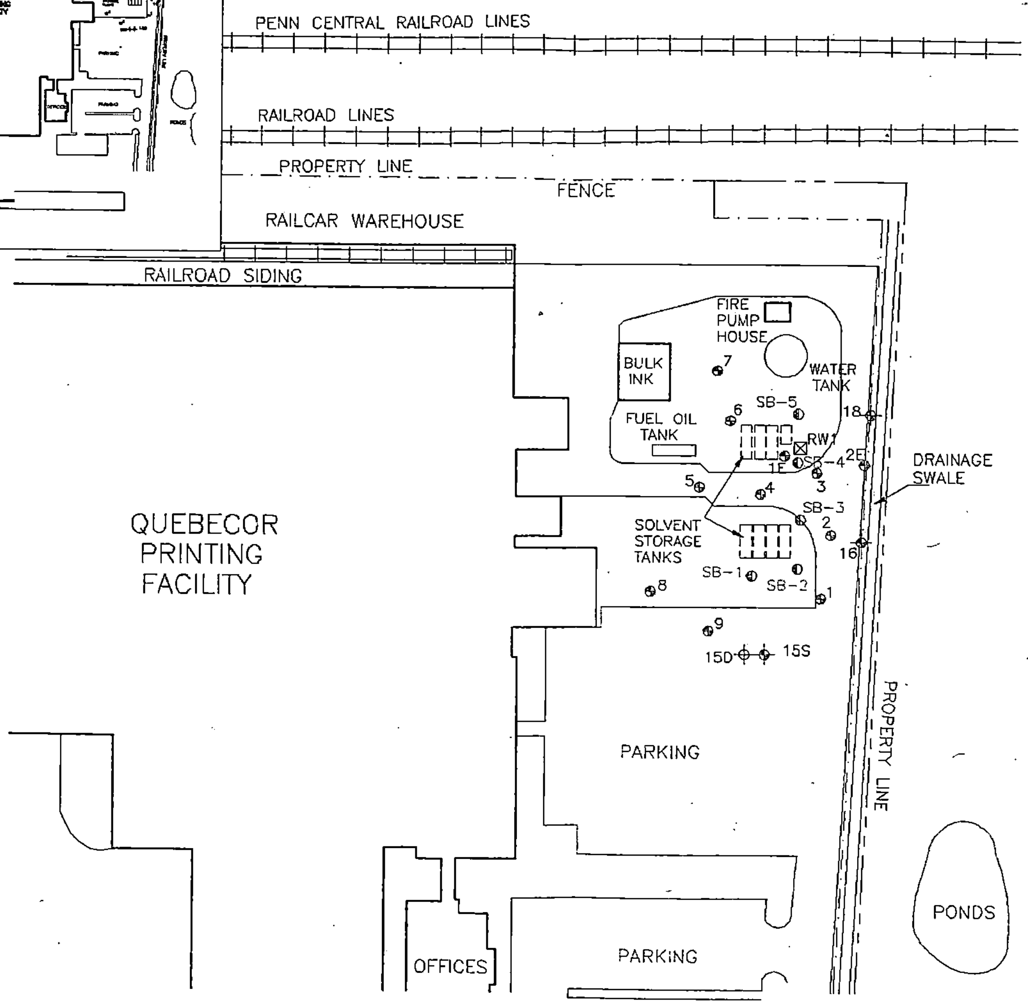

LEGEND

- MONITORING WELL
- RECOVERY WELL
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- SOIL BORING LOCATION
- B BENZENE
- T TOLUENE
- E ETHYLBENZENE
- X XYLENE
- ND NOT DETECTED

NOTES:
- ALL LAB RESULTS IN PARTS PER MILLION (ppm)
- NO SAMPLES WERE ANALYZED FROM SB-2 AND SB-3
- OVM READINGS ARE UNITLESS

µg/m

Rev 10/12/9

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-1	4' - 0	FOR 7'-9'
	5' - 0	B - ND
	7' - 1.7	T - 9.7
	7.5' - 1.9	E - ND
	8.5' - 2.5	X - ND

BORING NUMBER	OVM READINGS
SB-2	5' - 0.8
	9' - 1.5
	10' - 1.9
	11' - 1.1

BORING NUMBER	OVM READINGS
SB-3	3' - 1.7
	5' - 0.8
	6' - 0.3
	7' - 0.2
	8' - 0.7

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-4	5' - 15.5	FOR 5'-7'
	7.5' - 888	B - ND
	8.5' - 176	T - 15,000
	9' - 225	E - 380
	10' - 215	X - 1,800
	11' - 76	
	12' - 115	
	13' - 2	

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-5	4' - 1.5	FOR 11'-13'
	6' - 2.0	B - ND
	8' - 275	T - 2,100
	8.5' - 687	E - 77
	11.5' - 125	X - 510
	12.5' - 225	
	13' - 50	

SOIL BORING LOCATIONS SHOWING OVM READINGS AND LABORATORY ANALYTICAL RESULTS
13 MAY 1993

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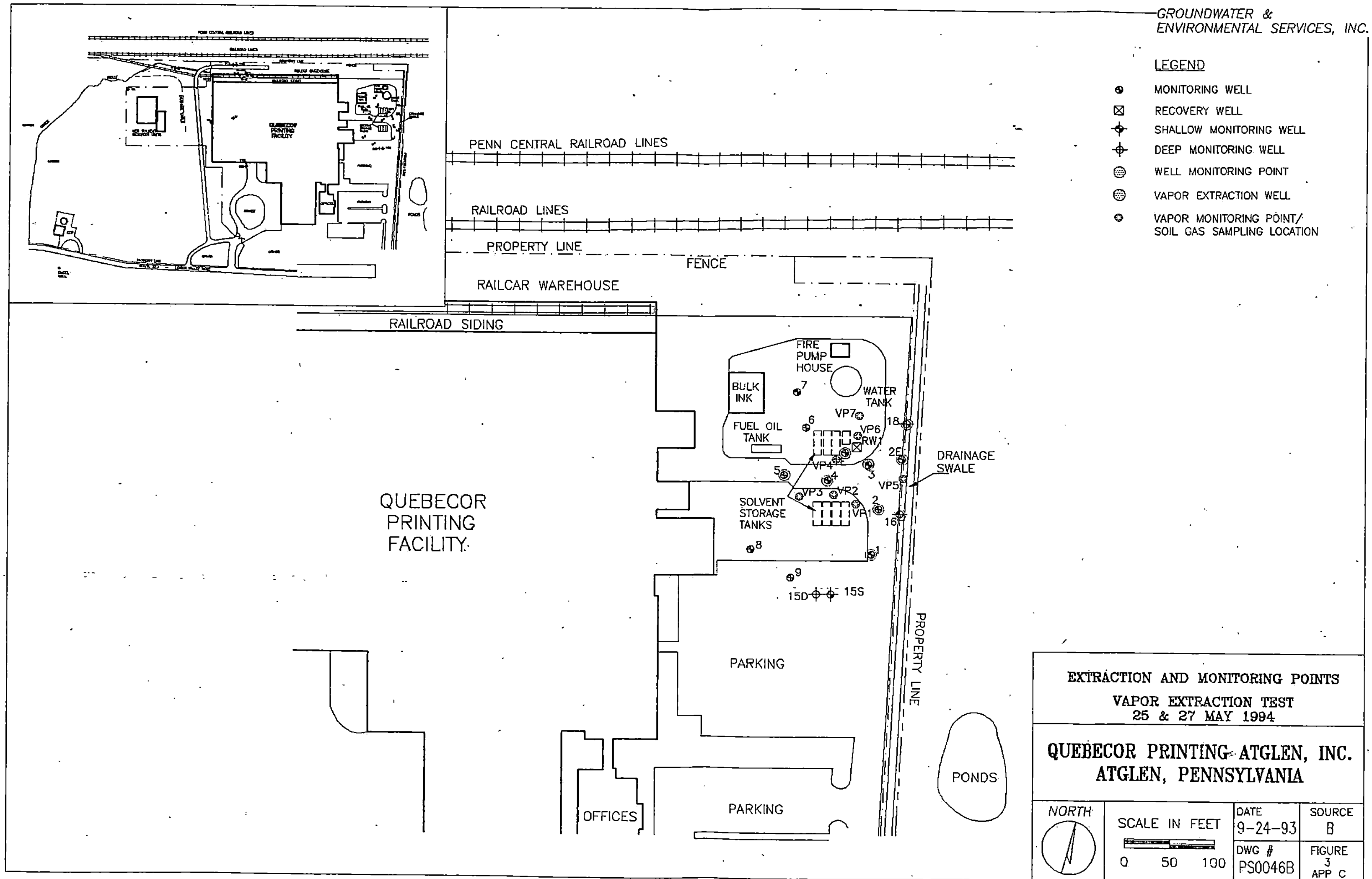
NORTH

SCALE IN FEET
0 50 100

DATE	SOURCE
9-24-93	B
DWG #	FIGURE
PS0046B	1 APP C

AR340263



EXTRACTION AND MONITORING POINTS

VAPOR EXTRACTION TEST
25 & 27 MAY 1994

QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA

DATE	SOURCE
9-24-93	B
DWG # PS0046B	FIGURE 3 APP C

AR340264

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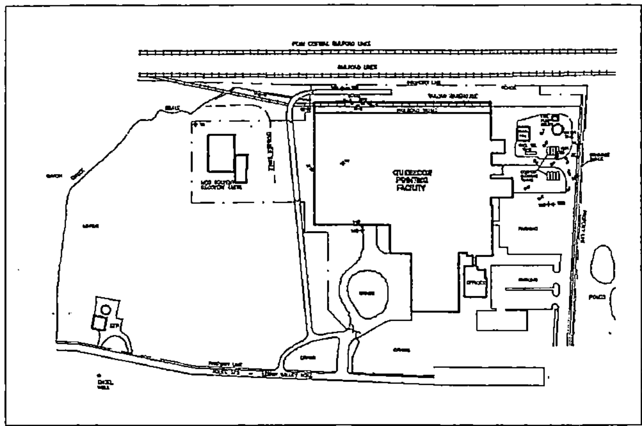

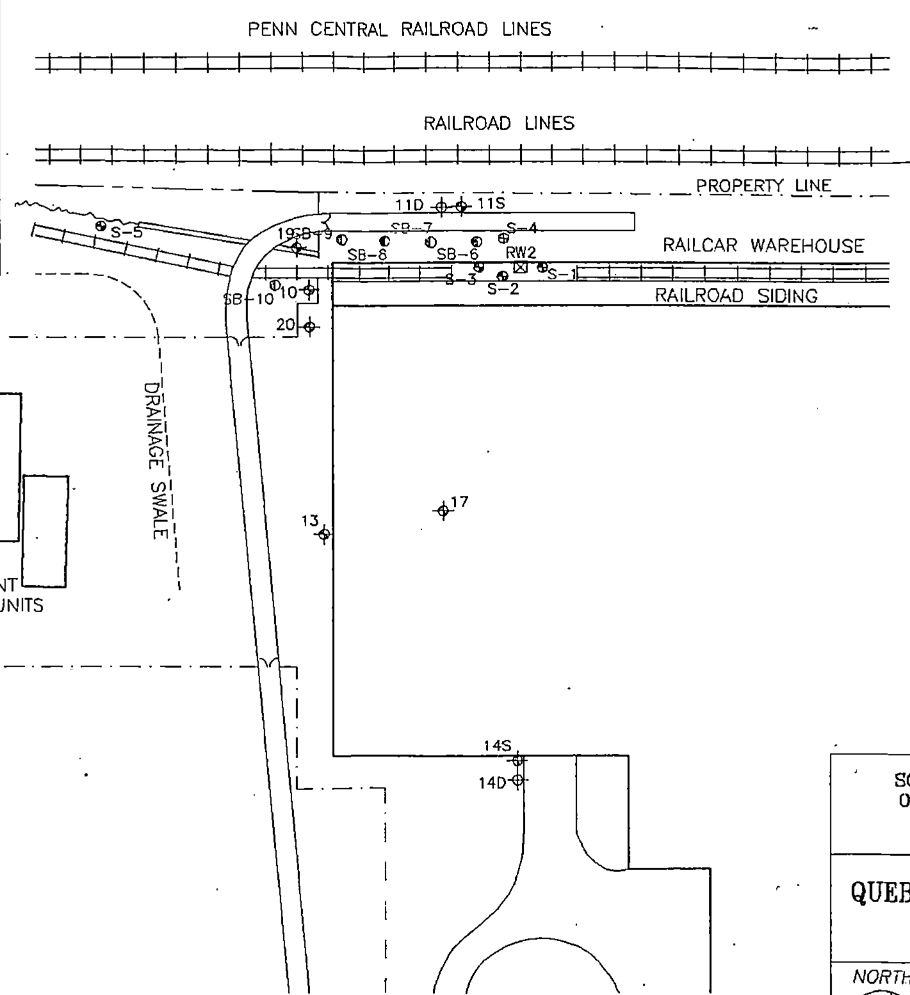

LEGEND

- MONITORING WELL
- RECOVERY WELL
- SHALLOW MONITORING WELL
- DEEP MONITORING WELL
- SOIL BORING LOCATION
- B BENZENE
- T TOLUENE
- E ETHYLBENZENE
- X XYLENE
- ND NOT DETECTED

NOTES:
- ALL LAB RESULTS IN PARTS PER MILLION (ppm)
- NO SAMPLES WERE ANALYZED FROM SB-8 AND AB-10
- OVM READINGS ARE UNITLESS

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-6	5' – 15.5 6.5' – 73 8' – 135 10' – 177 12' – 2.5 13' – 2.5	FOR 9'-11' B – ND T – 28,000 E – 1,800 X – 10,000

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-7	8.5' – 13.5 9.5' – 12.2 11' – 8.5 11.5' – 6 12.5' – 0.2 13' – 0 14' – 0	FOR 8'-10' B – ND T – 11 E – ND X – ND

BORING NUMBER	OVM READINGS
SB-8	5' – 0 7' – 0 9.5' – 0 10' – 0 10.5' – 0

BORING NUMBER	OVM READINGS	LAB RESULTS
SB-9	5' – 0 6' – 0 7' – 0 8' – 0 9' – 0 10' – 0 11' – 0	FOR 5'-7' B – ND T – 6 E – ND X – ND

BORING NUMBER	OVM READINGS
SB-10	7.5' – 78 9' – 63.5 10' – 59 11.5' – 10.9 12.5' – 2.1

SOIL BORING LOCATIONS SHOWING OVM READINGS AND LABORATORY ANALYTICAL RESULTS 13 MAY 1993

QUEBECOR PRINTING ATGLEN, INC.
ATGLEN, PENNSYLVANIA

NORTH	SCALE IN FEET	DATE	SOURCE
	0 50 100	9-24-93	B
		DWG # PS0046C	FIGURE 2 APP C

AR340265